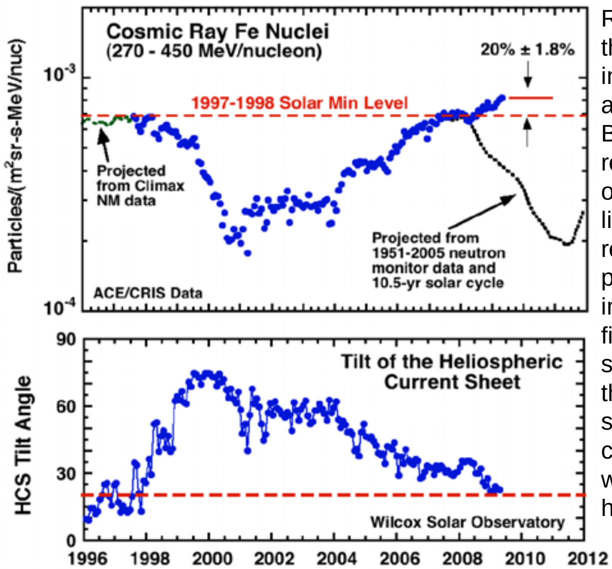
Appendix E—Mission Quad Charts

Appendix E-1
HSO Currently Operating Missions

- Advanced Composition Explorer (ACE)
- Aeronomy of Ice in the Mesosphere (AIM)
- Coupled Ion Neutral Dynamics Investigation (CINDI)
- Cluster
- Geotail
- Hinode
- Interstellar Boundary Explorer (IBEX)
- Reuven Ramaty High-Energy Solar Spectroscopic Imager (RHESSI)
- Solar and Heliospheric Observatory (SOHO)
- Solar-Terrestrial Relations Observatory (STEREO)
- Time History of Events and Macroscale Interactions During Subtorms (THEMIS)
- Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED)
- Transition Region and Coronal Explorer (TRACE)
- Two Wide-Angle Imaging Neutral-Atom Spectrometers (TWINS)
- Voyager Interstellar Mission (VIM)
- Wind

Advanced Composition Explorer (ACE)



Recent ACE data show that the 100 - 500 MeV/nuc intensities of all cosmic-ray species from B to Ni ($5 \le Z \le 28$) have reached their highest level of the space era. This most likely results from the record-low solar-wind pressure and interplanetary magnetic field, and the extended solar minimum. If the tilt of the heliospheric current sheet decreases further, cosmic-ray "super fluxes" will likely increase to even higher levels.

ACE: Advanced Composition Explorer

Measure and compare the composition of the solar corona, the solar wind, other interplanetary particle populations, the local interstellar medium, and galactic matter.

Key Information:

- Launch: 8/25/97
- Extension: 9/2012
- With STEREO, provides 3-pt network for solar-wind, CME, SEP, and CIR longitudinal studies
- Provides continuous, real-time space weather data

ACE Extended Mission Science Focus

ACE will address a very important question in Heliophysics:

•How do the compositions of the Sun, solar wind, solar particles, interstellar medium, and cosmic rays differ, and why?

Other questions addressed by ACE data include:

•How does the solar wind originate and evolve through the solar system?

•What is the structure of CMEs and other transients, and how do they evolve?

•How are seed particles fractionated and selected for acceleration to high energies?

•How are particles accelerated at the Sun, in the heliosphere, and in the Galaxy?

•How are energetic particles transported in the heliosphere and the Galaxy?

•What causes the solar wind, energetic particles, and cosmic rays to vary over the solar cycle?

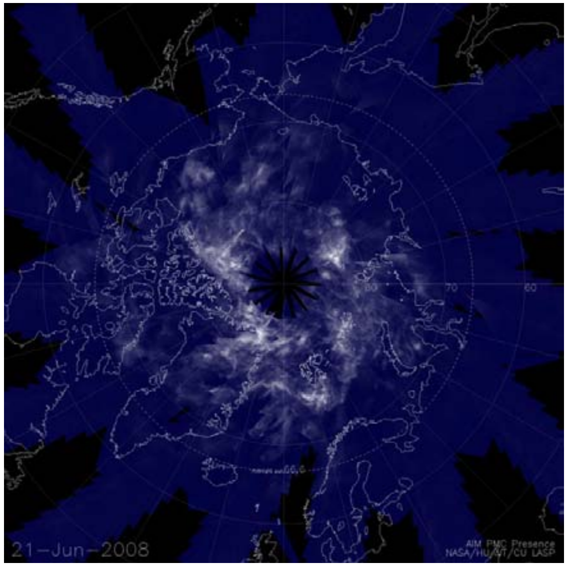
•How does the solar wind control the dynamic heliosphere

•How does the heliosphere interact with the interstellar medium?

•How do solar wind, energetic particles, and cosmic rays contribute to space weather over the solar cycle?

•What solar and interplanetary signatures can be used to predict space weather?

Aeronomy of Ice in the Mesosphere (AIM)



AIM image of noctilucent clouds over the Earth's north pole.

AIM: Aeronomy of Ice in the Mesosphere

Determine why polar mesospheric clouds form and vary.

Despite a significant increase in polar mesospheric clouds research in recent years, relatively little is known about the basic physics of these clouds at "the edge of space" and why they are changing. They have increased in brightness over time, are being seen more often and appear to be occurring at lower latitudes than ever before. It has been suggested (and debated) that these changes are linked to global change.

Key Information:

- Launch: 4/25/07
- Extension: 9/2012
- Uses measurements from: TIMED
- National Asset for Global Climate Change Research

AIM Extended Mission Science Focus

AIM is the first satellite mission that probes the basic physics of Polar Mesospheric Clouds or Noctilucent Clouds (PMCs/NLCs) on a global scale with high spatial resolution, and makes measurements that can provide information on how these clouds form and vary.

AIM addresses the following questions:

•Are there temporal variations in PMCs that can be explained by changes in solar irradiance and particle input?

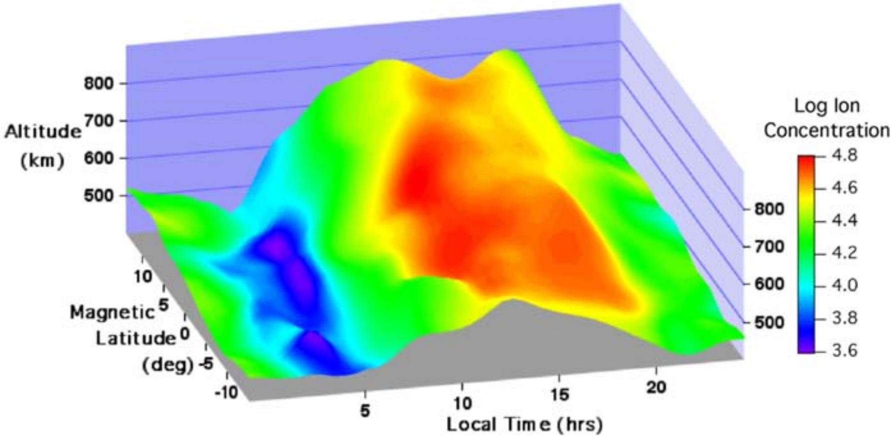
•What changes in mesospheric properties are responsible for north/south differences in PMC features?

•What controls interannual variability in PMC season duration and latitudinal extent?

•What is the mechanism of teleconnection between winter temperatures and summer hemisphere PMC's?

•An optimal funding study of gravity waves is proposed: What is the global occurrence rate of gravity waves outside the PMC domain?

Coupled Ion Neutral Dynamics Investigation (CINDI)



The top of the ionosphere has been observed continuously for the first time. It is a surface that is much closer to Earth than expected.

CINDI: Coupled Ion Neutral Dynamics Investigation

Understand how ion-neutral interactions control the behavior of the ionosphere and thermosphere.

CINDI observations are used to understand the various structures or boundaries of ionospheric plasma depletions, and the different densities of ions in the ionosphere at the equator. These can interfere with radio signals between the Earth and spacecraft in orbit, thus causing errors in tracking and loss of valuable communication.

Key Information:

- Launched on C/NOFS Satellite: 4/17/08
- In Prime Mission Until: 8/2010
- Potential Lifetime: 2015 (depends on solar activity)
- Orbit: 401 km by 867 km, 13 deg inclination
- Satellite provided by AFRL and Space Test Program

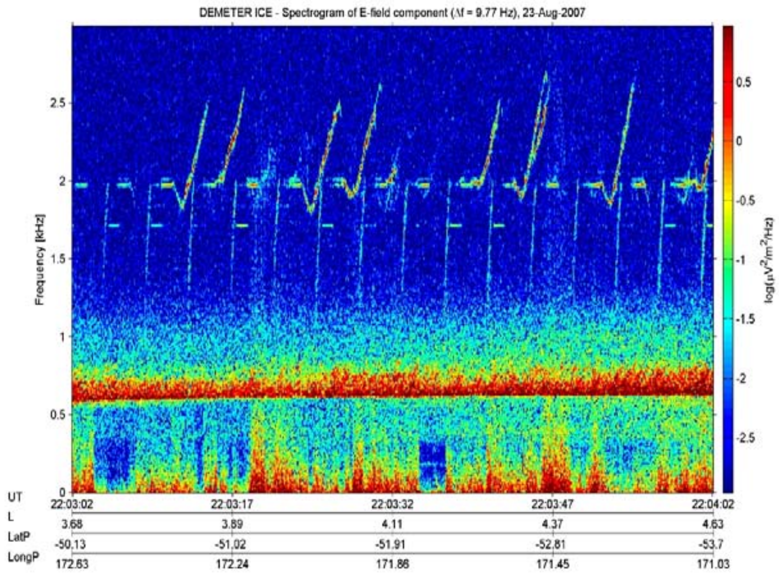
CINDI Prime Mission Science Focus

The CINDI mission is comprised of two instruments that measure the concentration and kinetic energy of the electrically charged particles (ions) and neutral particles in space as the satellite passes through them at the equator.

CINDI addresses the following questions:

- Determine the relationships between neutral winds and the daily variability of vertical plasma drifts.
- Discover the combination of neutral winds and plasma drifts that promotes the growth of plasma structure.
- Discover how the temporal evolution of plasma structure is influenced by neutral winds and plasma drifts.

Cluster



Cluster

Three-dimensional studies of plasma structures at the bow shock, magnetopause, dayside cusp, magnetotail and solar wind.

Cluster is a revolutionary probe of the magnetosphere and near-Earth solar wind. Its uniqueness derives from the ability of the four spacecraft, with their tetrahedral orbital configuration, to distinguish spatial and temporal properties of boundaries in space. Cluster has the flexibility to vary spacecraft separations, enabling repeated visits to regions at different spatial separations. Thus, Cluster is an active research tool.

Key Information:

- Launch: 7/16/00
- Extension: 9/2010
- Joint mission with ESA
- Important collaborations with THEMIS, STEREO

Cluster Extended Mission Science Focus

The mission will continue to explore the structure and dynamics of the bow shock and its role in producing energetic ions and electrons, a problem with fundamental scientific applications in space and astrophysics.

The scientific objectives involve the following:

•Fine-scale measurements at the bow shock and magnetopause; including solar wind inputs to Sun-Earth system; topside auroral acceleration region; plasmasphere & plasmapause; 3-component electric field to study radio and electrostatic emissions

•Plasma sheet processes at 12 RE (fine- and multi-scale measurements)

•Solar wind turbulence studies utilizing burst mode resolution and large volume

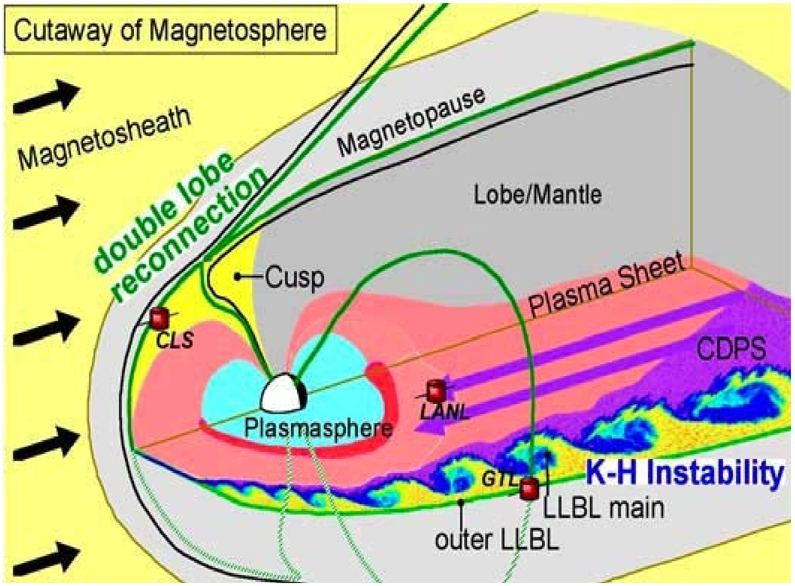
•Subsolar crossings of bow shock and magnetopause reconnection sites

•Low altitude cusp at 0.9 RE altitude

•Mid-range auroral acceleration region

•Plasma sheet processes at 9 RE
(fine and multi-scale measurements)

Geotail



GEOTAIL

Inventory the mechanisms controlling the entry and transport of plasma into the magnetosphere.

Geotail crosses all boundaries through which solar wind energy, momentum and particles must pass to enter the magnetosphere. Knowledge of the physical processes operating at these boundaries is vital to the understanding the flow of mass and energy from the Sun to Earth's atmosphere

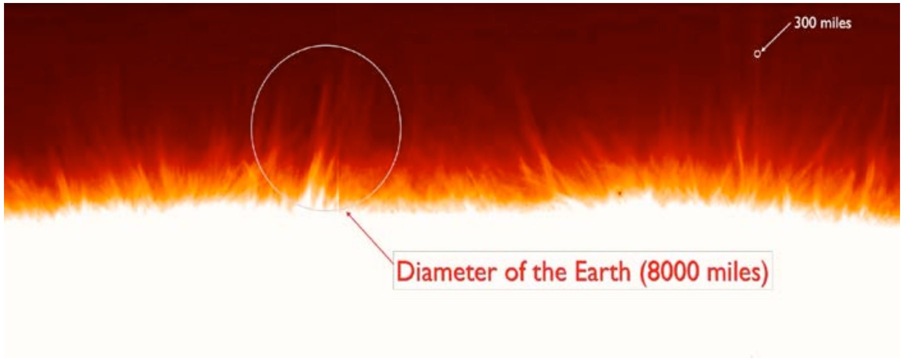
Key Information:

- Launch: 7/24/92
- Extension: 9/2010
- Joint mission with Japan

Geotail Extended Mission Science Focus

Extensive coverage of the magnetospheric boundary layer allows the deliniation of mechanisms controlling the entry and transport of plasma into the magnetosphere that is then energized to produce magnetic storms. Geotail also helps scientists define the location and physics of tail magnetic reconnection and particle acceleration and provides supplementary measurements to THEMIS to reveal the spatial and time scales of substorm phenomena in the magnetotail. Geotail spends about 35% of its time in the solar wind, providing near-Earth plasma and magnetic field measurements and acts as an important data source for global simulations. Another objective is determining energetic particle environments up to and including penetrating gamma rays.

Hinode



Hinode has obtained high resolution images of the poles of the Sun. One of these, seen above, shows a resolved spicule, which is approximately 300 miles across

Hinode:

Investigate the interaction between the Sun's magnetic field and the corona. The result will be an improved understanding of the mechanisms that power the solar atmosphere and drive solar eruptions. This information will tell us much about how the Sun generates magnetic disturbances and high-energy particle storms that propagate from the Sun to the Earth and beyond; in this sense, Hinode will help us predict "space weather."

Key Information:

- Launch: 9/23/06
- Extension: 9/2012
- Joint mission with Japan

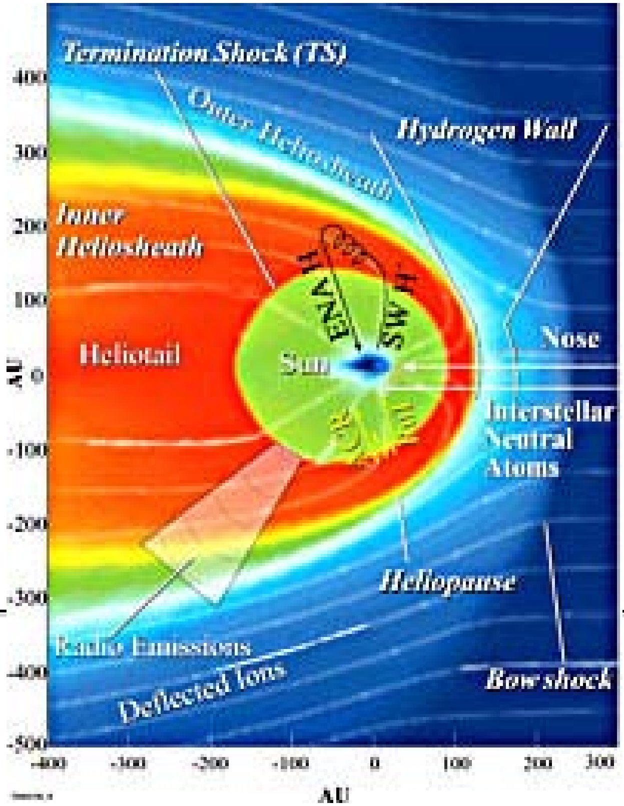
Hinode Extended Mission Science Focus

Hinode is using three instruments together to unravel basic information about the Sun.

Hinode's goals are:

- To understand how energy generated by magnetic-field changes in the lower solar atmosphere (photosphere) is transmitted to the upper solar atmosphere (corona),
- To understand how that energy influences the dynamics and structure of that upper atmosphere, and
- To determine how the energy transfer and atmospheric dynamics affects the interplanetary-space environment.

Interstellar Boundary Explorer (IBEX)



IBEX: Interstellar Boundary Explorer

Image the 3-D boundary region of our heliosphere

Key Information:

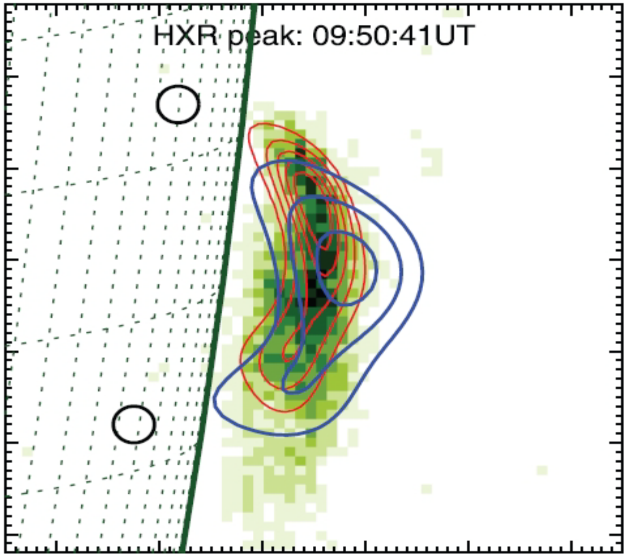
- Launch: 10/19/08
- In Prime Mission Until: 10/2010
- Uses measurements from: Voyager, Ulysses, ACE, Wind

IBEX Prime Mission Science Focus

IBEX's sole, focused science objective is to discover the global interaction between the solar wind and the interstellar medium. IBEX achieves this objective by taking a set of global energetic neutral atom (ENA) images that answer four fundamental science questions:

- What is the global strength and structure of the termination shock?
- How are energetic protons accelerated at the termination shock?
- What are the global properties of the solar wind flow beyond the termination shock and in the heliotail?
- How does the interstellar flow interact with the heliosphere beyond the heliopause?

Reuven Ramaty High-Energy Solar Spectroscopic Imager (RHESSI)



RHESSI and Hinode images of a coronal source at the time of the hard X-ray peak of a flare on 21 Nov. 2006. The thermal source is seen in the Hinode/XRT image at ~2 keV (green) and in the 5-8 keV RHESSI image (red contours). The non-thermal source appears at a slightly higher altitude in the 18-30 keV RHESSI image (blue contours). The solar limb and lines of solar latitude and longitude are shown by the solid and broken lines while the two black circles show the presumed locations of the occulted footpoints on the far side of the Sun.

RHESSI: Reuven Ramaty High-Energy Solar Spectroscopic Imager

Investigate particle acceleration and energy release in solar flares.

Investigate particle acceleration and energy release in solar flares through imaging and spectroscopy of hard X-ray (HXR)/gamma-ray continua emitted by energetic electrons, and of gamma-ray lines produced by energetic ions. The single RHESSI instrument provides high resolution imaging and spectroscopy measurements over the broad energy range from soft X-rays (3 keV) to gamma-rays (17 MeV).

Key Information:

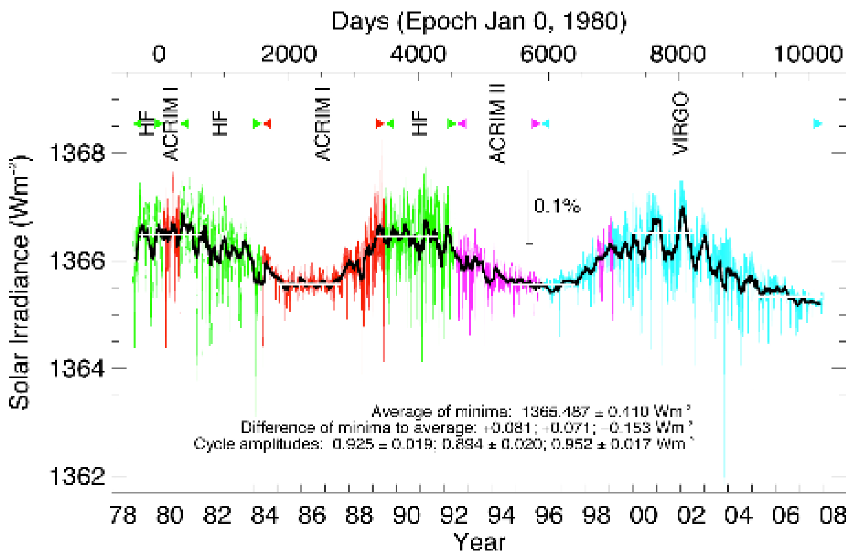
•Launch: 02/05/02

•Extension: 9/2012

RHESSI Extended Mission Science Focus

Integrate new RHESSI flare observations on the rise towards solar maximum with the observations of the other Heliophysics Great Observatory (HGO) missions, particularly the newer missions - STEREO, Hinode, and the Solar Dynamics Observatory, and with the Gamma-ray Large Area Space Telescope (GLAST). Comparing observations from all these missions will enable new studies of energy release and particle acceleration processes in flares and CMEs that are more comprehensive than have previously been possible. These include studies of the processes leading up to the flare/CME trigger point, the initiation of the energy release itself possibly best revealed by the non-thermal effects seen with RHESSI even in the weakest microflares, the location of the electrons and ions in more large gamma-ray flares to address the differences found in earlier events, the location and properties of the coronal hard-ray sources seen in many flares with RHESSI, and the detailed temporal and spatial comparisons between flares and their associated CMEs.

Solar and Heliospheric Observatory (SOHO)



SOHO: Solar and Heliospheric Observatory

Understand the causes and mechanisms of CME initiation and propagation.

A white-light coronagraph to provide a Sun-Earth line view of both the evolution of and transient events in the solar corona; helioseismology and EUV imaging instruments provide baseline intercalibration with SDO analogs before end of life in order to extend our measurements to a complete, 22-year solar magnetic cycle; continued monitoring of the H I Lyman alpha resonant scattering corona, solar wind, and solar energetic particles.

Key Information:

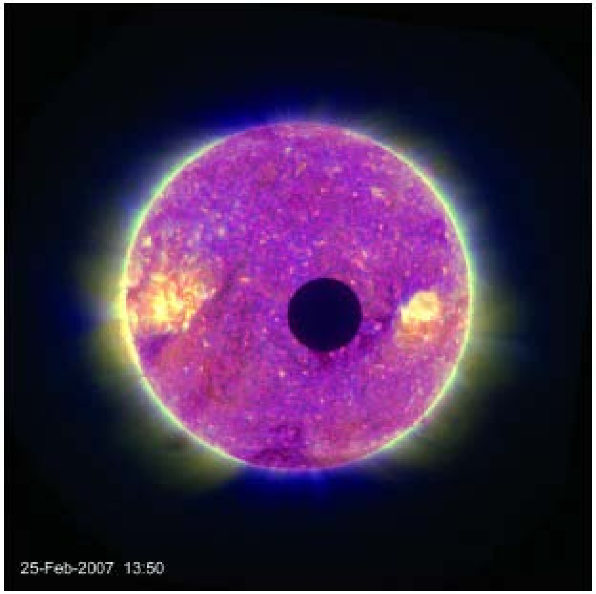
- Launch: 12/02/95
- Extension: 9/2012
- Joint mission with ESA
- National Resource for Space Weather Prediction

SOHO Extended Mission Science Focus

In conjunction with SDO and STEREO:

- Understand the causes and mechanisms of CME initiation, and the propagation of CME's through the heliosphere
- Continue to monitor the Total Solar Irradiance
- Monitor the H1 Lyman alpha corona in order to improve our understanding of solar wind acceleration and the distributions of seed particles accelerated as SEPs
- Continue measurement of interstellar winds
- Continue the search for global solar g-modes
- Provide data enabling predictions of solar energetic particles during manned space missions

Solar-Terrestrial Relations Observatory (STEREO)



Moon transit across the solar disk as viewed from STEREO. The transit has been used to calibrate STEREO's remote-sensing instrumentation.

STEREO: Solar-Terrestrial Relations Observatory

Traces the flow of energy and matter from the Sun to Earth as well as reveals the 3D structure of coronal mass ejections (CMEs) to understand why they happen.

CMEs are powerful eruptions that can blow up to 10 billion tons of the Sun's atmosphere into interplanetary space. Traveling away from the Sun at speeds of approximately one million mph (1.6 million km/h), CMEs can create major disturbances in the interplanetary medium and trigger severe magnetic storms when they collide with Earth's magnetosphere.

Key Information:

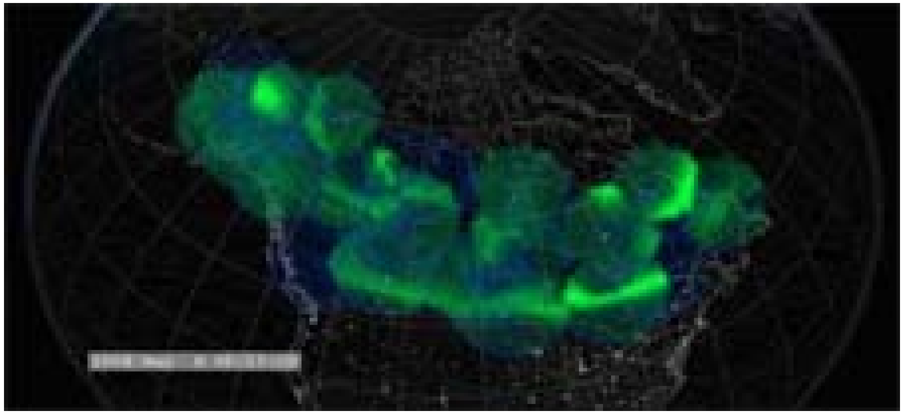
- Launch: 10/25/06
- Extension: 9/2012
- National Resource for Space Weather Prediction

STEREO Extended Mission Science Focus

Detailed Objectives:

- Understand the causes and mechanisms of CME initiation
- Characterize the propagation of CMEs through the heliosphere
- Discover the mechanisms and sites of energetic particle acceleration in the low corona and the interplanetary medium
- Develop a 3D time-dependent model of the magnetic field topology, temperature, density, and velocity structure of the ambient solar wind

Time History of Events and Macroscale Interactions During Subtorms (THEMIS)



A collection of ground-based All-Sky Imagers (ASI) captures the aurora brightening caused by a substorm.

<u>THEMIS: Time History of Events and Macroscale Interactions During Subtorms</u>

Resolve the controversy concerning the spatial and temporal development of magnetospheric substorms

<u>Key Information:</u>

•Launch: 2/17/07

•Extension: 9/2012

•Orbits: 5 spacecraft (innermost 3 spacecraft after 10/09)

•P1, 1.2 x 31.7 RE, i = 3.2°, T = 94.0 hours

•P2, 1.3 x 19.6 RE, i = 6.7°, T = 47.5 hours

•P3, 1.4 x 11.8 RE, i = 6.5°, T = 23.9 hours

•P4, 1.4 x 11.8 RE, i = 7.1°, T = 23.9 hours

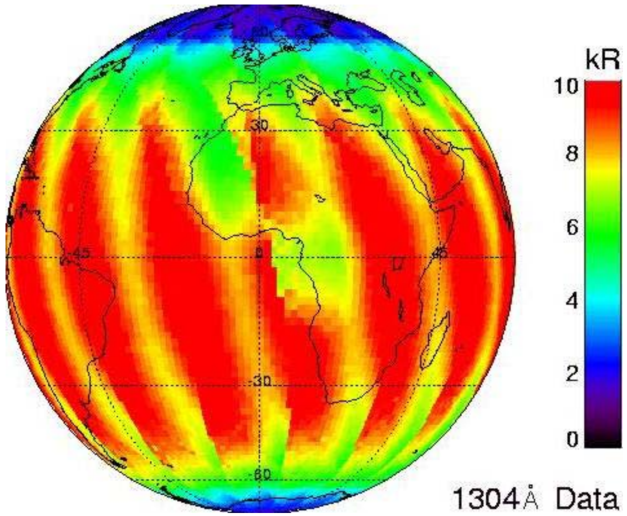
•P5, 1.5 x 9.9 RE, i = 11.5°, T = 19.2 hours

THEMIS employs 5 identical identical spacecraft with comprehensive plasma and magnetic field instrumentation to pinpoint when and where disturbances in the Earth's magnetotail occur that drive geomagnetic substorms, as manifested in the form of brilliant auroral displays over the northern and southern polar caps. A dedicated array of ground magnetometers and all-sky imagers covering northern Northern America places the spacecraft observations of these magnetotail phenomena in context and connects them to their ionospheric consequences. Secondary and tertiary mission objectives include ring current, foreshock, and magnetopause phenomena.

<u>THEMIS Extended Mission Science Focus</u>

•During the extended mission, the three innermost THEMIS spacecraft will employ new interspacecraft separation distances to study reconnection and current disruption on the subsolar magnetopause and in the near-Earth magnetotail.

Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED)



TIMED observes effect of solar eclipse of March 29, 2006 on thermosphere

TIMED: Thermosphere Ionosphere Mesosphere Energetics and Dynamics

Characterize the physics, dynamics, energetics, thermal structure, and composition of the Earth's mesosphere-lower thermosphere-ionosphere (MLTI).

Key Information:

•Launch: 12/07/01

•Extension: 9/2012

•Orbit: 625-km circular and 74.1º inclination

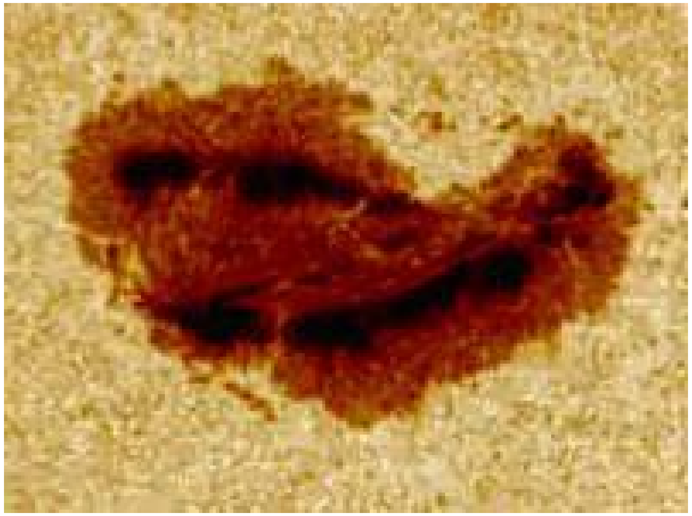
TIMED observed the Earth's upper atmosphere system during the declining and minimum phase of the solar cycle, which has been marked by some of the largest geomagnetic storms on record (forcing from above) and three QBO (quasi-biennial oscillation) stratospheric cycles (forcing from below). These are the only long-baseline observations of this system and they demonstrate the complexities of this nonlinear system and the mutual interactions of the coupling processes at work.

TIMED Extended Mission Science Focus

•Characterize and understand the solar cycle-induced variability of the mesosphere-lower thermosphere-ionosphere region

•Address the processes related to human-induced variability of the mesosphere-lower thermosphere.

Transition Region and Coronal Explorer (TRACE)



The TRACE spacecraft identified one possible source of the magnetic stress that causes flares: sunspots that rotate, storing energy in the magnetic field. Credit: NASA/LMSAL

TRACE: Transition Region and Coronal Explorer

TRACE explores the three-dimensional magnetic structures that emerge through the visible surface of the Sun - the Photosphere - and define both the geometry and dynamics of the upper solar atmosphere: he Transition Region and Corona.

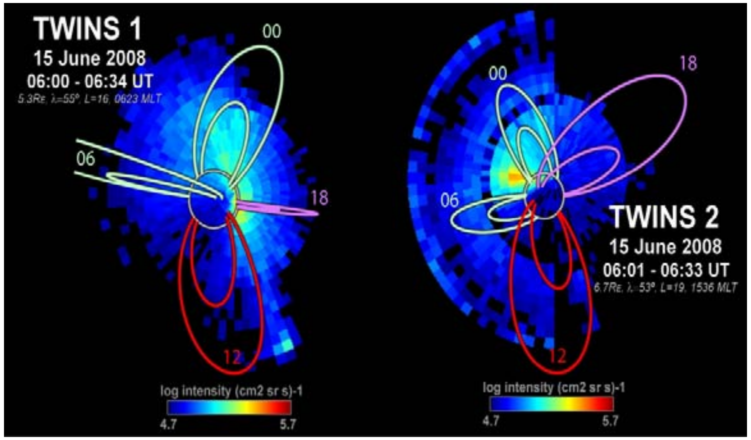
Key Information:

- Launch: 04/01/98
- Extension: 10/2009

TRACE Extended Mission Science Focus

To simultaneously capture high spatial and temporal resolution images of the transition region. The TRACE data will provide quantitative observational constraints on the models and thus stimulate real advances in our understanding of the transition region. The data also allows us to follow the evolution of magnetic field structures from the solar interior to the corona, investigate the mechanisms of the heating of the outer solar atmosphere, and investigate the triggers and onset of solar flares and mass ejections.

Two Wide-Angle Imaging Neutral-Atom Spectrometers (TWINS)



First-light stereo ENA image obtained by TWINS on 15 June 2008. The color indicates ENA flux. The Earth is in the center of each image, surrounded by dipole magnetic field lines at 4 and 8 Earth radii equatorial crossing-points. Field lines at noon (dusk) are colored red (lavender).

TWINS: Two Wide-Angle Imaging Neutral-Atom Spectrometers

Establish the global connectivities and causal relationships between processes in different regions of the Earth's magnetosphere.

Key Information:

•Mission of Opportunity non-NASA U.S. Govt. spacecraft

•Launch: 2006 and 2008

•Stereo ENA Observations Began: June 2008

•Prime Phase: 5/2010 (currently-funded operations), 2011 (science data analysis)

TWINS is obtaining the first stereoscopic neutral atom imaging of the magnetosphere from two widely spaced, high-altitude, high-inclination spacecraft. By imaging charge exchange neutral atoms over a broad energy range (~1–100 keV) using identical instruments on two spacecraft, TWINS enables the three-dimensional (3-D) visualization of the magnetosphere and the resolution of large scale structures and dynamics within the magnetosphere for the first time.

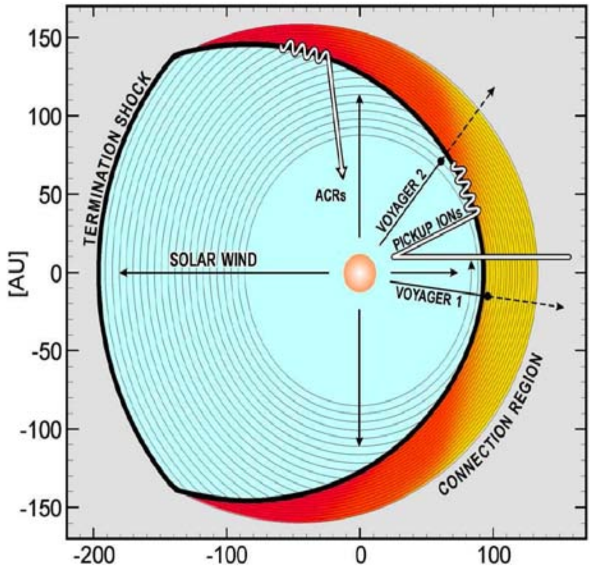
TWINS Extended Mission Science Focus

•Determine the structure and evolution of the stormtime magnetosphere.

•Understand the energization and transport of magnetospheric plasma populations.

•Characterize the stormtime sources and sinks of energetic magnetospheric plasma.

Voyager Interstellar Mission (VIM)



Artist's conception of the magnetic field lines of the solar wind interacting with a blunt termination shock. The geometry of the shock has implications for the dynamics of cosmic rays measured at Earth. The Voyagers crossed this boundary in 2004 and 2007.

VIM: Voyager Interstellar Mission

Explore the interaction of the heliosphere with the local interstellar medium.

The Voyager spacecraft continue their epic journey of discovery, traveling through a vast unknown region of our heliosphere on their way to the interstellar medium. Both Voyagers are now traversing the heliosheath with the first crossings of the heliopause and the first in situ observations of the interstellar medium still to come.

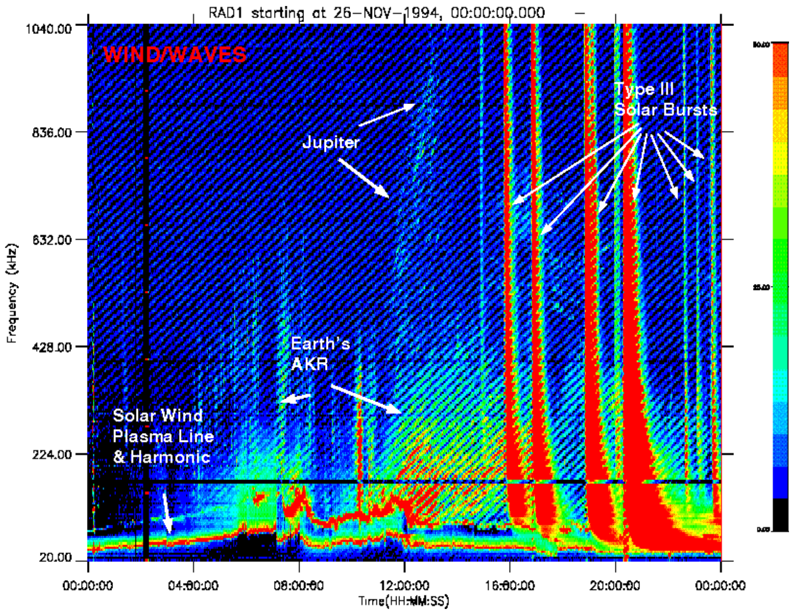
Key Information:

- Launches: 1977
- Extension: 9/2012
- Potential Lifetime: ~2020

VIM Extended Mission Science Focus

Study the heliosheath: major mysteries remain unresolved, such as the source of, and acceleration mechanism for the anomalous cosmic rays. VIM, in combination with IBEX should be able to solve some of these questions. The nature of the solar wind turbulence and the behavior of major solar wind structures downstream of the termination shock will also be examined by the VIM.

Wind



as

Wind

Make accurate measurements of interplanetary conditions close to the L1 point, to remotely sense interplanetary disturbances for predictive purposes, and to study the properties of the inner Heliosphere.

Key Information:

- Launch: 11/01/94
- Extension: 9/2012

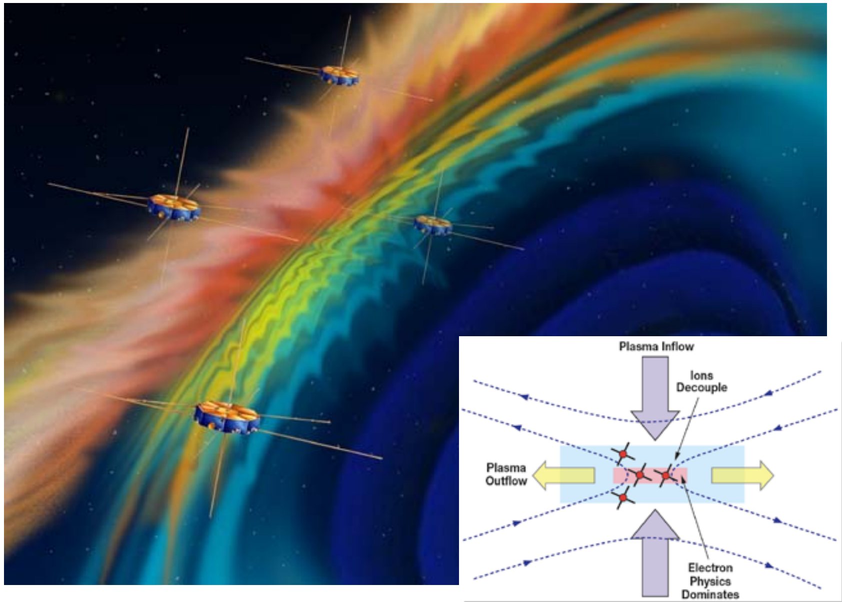
Wind Extended Mission Science Focus

Provide a third spacecraft to collaborate with and supplement investigations by the STEREO spacecraft and continue long-term studies of solar events and conditions in the inner heliosphere.

Appendix E-2
Missions In Development

- Magnetospheric Multiscale (MMS)
- Radiation Belt Storm Probes (RBSP)
- Solar Dynamics Observatory (SDO)
- Solar Orbiter (SO)
- Solar Probe Plus (SP+)

Magnetospheric Multiscale (MMS)



Measurement Strategy:

- Four identically instrumented spin-stabilized spacecraft launched on a single expendable launch vehicle and configured in a tetrahedral formation to probe the dayside and nightside reconnection regions.

Launch: August, 2014

Orbit:

- Phase 1: Dayside magnetopause orbit (1.2 RE by 12 RE)
- Phase 2: Magnetotail orbit: (1.2 RE by 25 RE)

MMS: Magnetospheric Multiscale Science Objectives

- Understand the microphysics of magnetic reconnection by determining the kinetic processes occurring in the electron diffusion region that are responsible for collisionless magnetic reconnection, especially how reconnection is initiated.

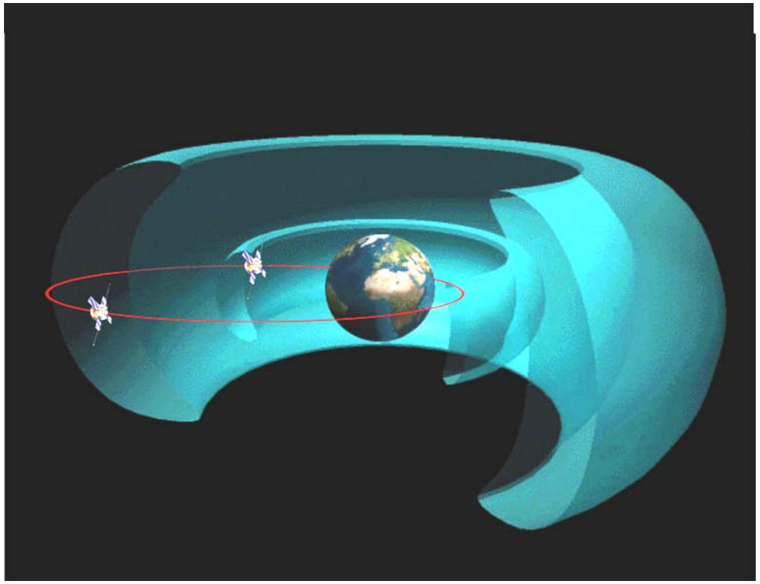
Specifically, and in priority order:

- Determine the role played by electron inertial effects and turbulent dissipation in driving magnetic reconnection in the electron diffusion region.
- Determine the rate of magnetic reconnection and the parameters that control it.
- Determine the role played by ion inertial effects in the physics of magnetic reconnection.

MMS was ranked the highest-priority moderate-sized mission in the 2003 solar and space physics decadal survey of the National Research Council.

- **Science Payload:** The four MMS spacecraft will carry identical suites of plasma analyzers, energetic particle detectors, magnetometers, and electric field instruments as well as a device to prevent spacecraft charging from interfering with the highly sensitive measurements required in and around the diffusion regions.
- The plasma and fields instruments will measure the ion and electron distributions and the electric and magnetic fields with unprecedented high (millisecond) time resolution and accuracy. These will enable MMS to locate and identify the small (10's of km) and rapidly moving (10-100 km/s) diffusion regions, to determine their size and structure, and to discover the mechanisms by which the plasma and the magnetic field become decoupled and the magnetic field is reconfigured.
- MMS will make the first unambiguous measurements of plasma composition at reconnection sites, while energetic particle detectors will remotely sense the regions where reconnection occurs and determine how reconnection processes produce large numbers of energetic particles.

Radiation Belt Storm Probes (RBSP)



Measurement Strategy:

- Measure temporal variations and radial profiles of energetic charged particles, electric and magnetic fields in response to varying solar wind conditions

Launch: May, 2012

Orbit:

- Two spacecraft in nearly identical, low-inclination (<18°), highly elliptical (apogee 5.2-6.0 RE; perigee < 1000km) 'chasing' orbits distinguish spatial from temporal variations.
- Simultaneous two-point measurements discriminate between temporal and spatial phenomena, distinguish local acceleration from radial transport.
- Evolving spacecraft orbits provide observations over a wide range of radial and azimuthal separations.

RBSP: Radiation Belt Storm Probes Science Objectives

- Provide Understanding, ideally to the point of predictability, of how populations of relativistic electrons and penetrating ions in space form or change in response to variable inputs of energy from the Sun.

There are three overarching science questions:

- Which physical processes produce radiation belt enhancement events?
- What are the dominant mechanisms for relativistic electron loss?
- How do ring current and other geomagnetic processes affect radiation belt behavior?

Science Payload:

1. Energetic Particle, Composition, and Thermal Plasma (ECT) Instrument Suite.
2. Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS).
3. Electric Field and Waves Instrument (EFW).
4. Radiation Belt Storm Probes Ion Composition Experiment (RBSPICE).
5. Relativistic Particle Spectrometer (RPS)

These instruments will provide the measurements needed to characterize and quantify the plasma processes that produce very energetic ions and relativistic electrons. The instruments will measure the properties of charged particles that comprise the Earth's radiation belts, the plasma waves which interact with them, the large-scale electric fields which transport them, and the particle-guiding magnetic field

Solar Dynamics Observatory (SDO)

Key Information:

- NASA GSFC developed and managed the build of the spacecraft bus and ground system as well as the integration and testing of the Observatory
- Five-year prime mission operations include using two dedicated Ka-band antennas that receiveda 150 Mbps data stream continuously
- November 2009 launch on Atlas V from KSC to a final Geosynchronous Earth Orbit, inclined 28.5 degrees
- Data streamed directly to Science Operations Centers without in-space storage or preliminary data reduction.

SDO: Solar Dynamics Observatory Science Objectives

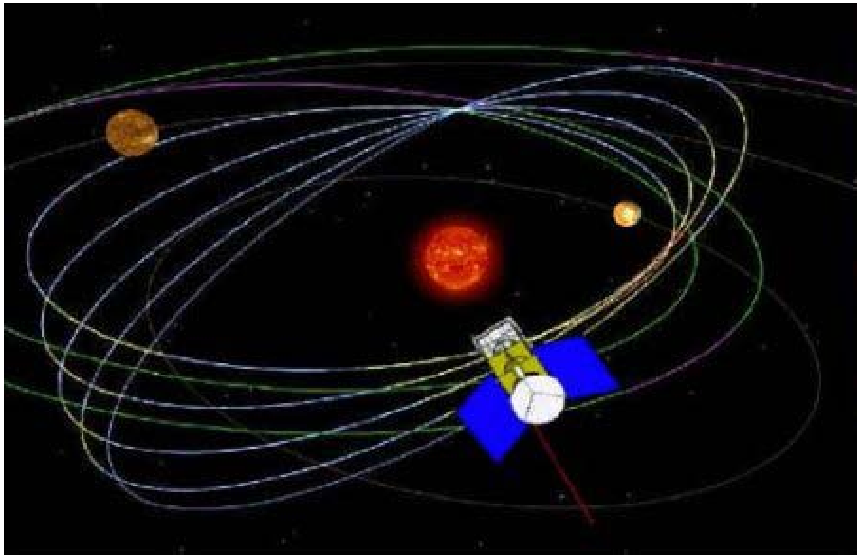
- Understand the nature and source of the solar variability that affects life and society
- Measure solar parameters that are necessary to improve understanding of the mechanisms responsible for the Sun's variability on various timescales
- Monitor the Sun's variable radiative, particulate, and magnetic plasma outputs that impact the surrounding heliosphere.

SDO, already in development in 2003, has been endorsed by the 2003 solar and space physics decadal survey of the National Research Council.

Measurement Strategy

- Helioseismic Magnetic Imager (HMI): Images the Sun's helioseismic and magnetic fields to understand the Sun's interior and magnetic activity
- Atmospheric Imaging Assembly (AIA): Multiple simultaneous, high-resolution images of the corona over a wide range of temperatures
- Extreme Ultraviolet Variability Experiment (EVE): Measures the extreme ultraviolet (EUV) irradiance to understand solar variations

Solar Orbiter



Key Information:

- ESA-led mission where ESA is providing the spacecraft bus, integration of instruments onto the bus, mission operations, and overall science operations.
- Science investigations/instruments provided by NASA and ESA member states
- NASA-provided launch in 2017 to in-ecliptic perihelion passes where Observatory is nearly co-rotating with the Sun. Follow with multiple Venus gravity assists to raise the orbital inclination to progressively higher heliolatitudes, reaching 27.5 degrees by end of seven-year prime mission lifetime.

Solar Orbiter Science Objectives

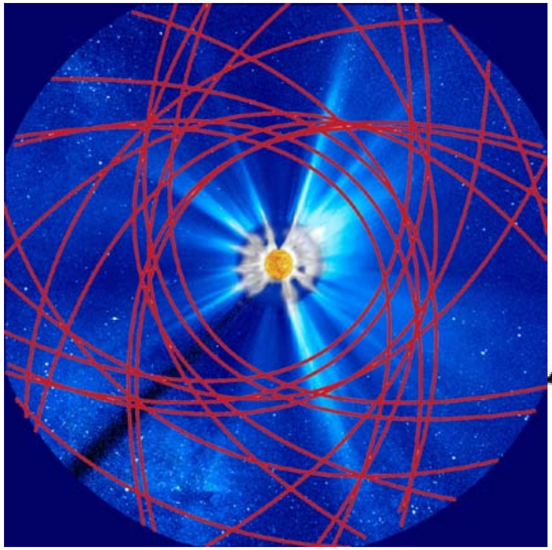
- To determine in-situ the properties and dynamics of plasma, fields and particles in the near-Sun heliosphere
- To survey the fine detail of the Sun's magnetised atmosphere
- To identify the links between activity on the Sun's surface and the resulting evolution of the corona and inner heliosphere, using solar co-rotation passes
- To observe and characterize the Sun's polar regions and equatorial corona from high latitudes

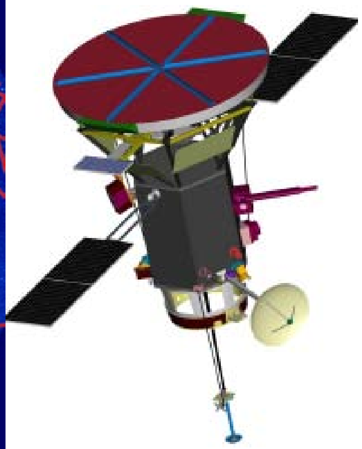
Solar Orbiter was ranked the fourth priority small-sized mission in the 2003 solar and space physics decadal survey of the National Research Council.

Measurement Strategy

- By approaching as close as 48 solar radii, Solar Orbiter will view the solar atmosphere with high spatial resolution and combine this with measurements made in-situ.
- Over the extended mission periods Solar Orbiter will deliver images and data that will cover the polar regions and the side of the Sun not visible from Earth.
- The in-situ instruments consist of detectors for observing particles and events in the immediate vicinity of the spacecraft: the charged particles and magnetic fields of the solar wind, radio and magnetic waves in the solar wind, and energetic charged particles flung out by the Sun.
- The remote-sensing instruments will observe the Sun in strong emissions of short-wavelength ultraviolet rays. Tuned to these will be a full-Sun and high-resolution imager and a high-resolution spectrometer. The outer atmosphere will be revealed by visible-light coronagraphs. To measure local magnetic fields, Solar Orbiter will carry a high-resolution magnetograph.

Solar Probe Plus (SP+)





Key Information:
- Launch date 2018
- Non-nuclear power surce
- Flybys: 7 Venus flybys
- Final solar orbit
  - Perihelion: 9.5 Rs
  - Aphelion: 0.73 AU
  - Inclination: 3.4 deg from ecliptic
  - Orbit period: 88 days
- Launch to 1st perihelion < 0.25 AU: 88 days
- Launch to min perihelion: 6.39 years
- Mission duration (3 passes): ~7 years
- Max aphelion: 1 AU

SP+: Solar Probe Plus Science Objectives
- Determine the structure and dynamics of the magnetic fields
  at the sources of the fast and slow solar wind.
- Trace the flow and elucidate the thermodynamics of the energy that heats the solar corona and accelerates the solar wind.
- Determine what mechanisms accelerate and transport energetic charged particles.
- Explore dusty plasma phenomena and their influence on the solar wind and energetic particle formation.

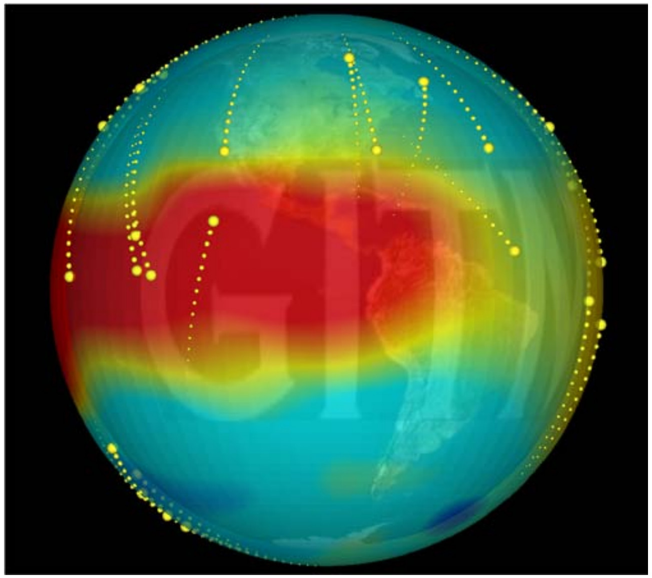
SP was ranked the highest priority large-sized mission in the 2003 solar and space physics decadal survey of the National Research Council.

Measurement Strategy
- Statistical survey of outer corona
  - ~1000 hours inside 20 Rs
  - Excellent sampling of all types of SW
  - New concept allows more time within Alfvén critical point
- Complete In-Situ measurements
  - Plasma, suprathermals, energetic particles, magnetic fields, waves, n0/g, and dust
- On-board remote-sensing observations
  - Hemispheric white light imaging provides context for in-situ measurements
- Coordinated remote-sensing from other assets can view solar source regions
  - ~500 hours while SP+ is inside 20 Rs
- SP+ funded Participating Scientist program
  - Includes extensive theory & modeling components

Appendix E-3
Heliophysics Town Hall 2008: Mission Concepts

- Armada
- Coronal Magnetism, Plasma, and Activity Studies from Space
- Dynamics of the Global Ionosphere-Thermosphere System (DyGITS)
- Electrodynamics Observations with Numerous Satellites (EONS)
- Explorer of the Coupled Ionosphere Thermosphere Electrodynamics (ExCITE)
- Fine-scale Advanced Coronal Transition-region Spectrograph (FACTS)
- Focusing Optics X-ray Solar Imager (FOXSI)
- FUV and EUV Imaging of the Thermosphere and Ionosphere from GEO
- Gamma-Ray Imager/Polarimeter for Solar Flares (GRIPS)
- Geospace Electrodynamic Connections
- Geospace Magnetospheric and Ionospheric Neutral Imager (GEMINI)
- Geospace Observer from Large Distance (GOLD)
- Global-scale Observations of the Limb and Disk (GOLD)
- Heliophysical Plasma Physics In Lunar Orbit (HILO)
- Heliosphere Explorer (HELIX)
- High-latitude Dynamic E-Field (HiDEF) Explorer
- Imaging Geospace Electrons Using Thomson Scattering
- In situ Diagnostics of Universal Plasma Processes
- Interstellar Explorer—An Interstellar Precursor Mission
- IT Constellation
- Lunar Dust Observatory
- Lunar Surface Solar Origins explorer (LunaSSOX)
- Magnetic Reconnection in the Corona (MARCO)
- Magnetospheric Constellation
- Magnetospheric Sentinels
- Maneuverable Near-Space Platform
- Neutral Ion Coupling Explorer (NICE)
- Paired Ionosphere-Themosphere Orbiters (PITO)
- PERSEUS—Investigating global heliospheric dynamics from L1
- The Profile Mission
- Radio Observatory for Lunar Sortie Science (ROLSS)
- Reconnection and Microscale Mission
- Solar Activity Farside Investigation (SAFARI)
- Solar Imaging Radio Array (SIRA)
- Solar Magnetized Regions Tomograph (SMART)
- Solar-C Plan A
- Solar-C Plan B
- Solar Polar Imager (aka POLARIS)
- Space Weather Imaging Sentinel (SWIS)
- Stellar Imager (SI)
- Storm-Time Observations by Remote and In Situ Measurements (STORM)
- Thermosphere Ionosphere Global and Regional Imaging in Space and Time (TIGRIST)
- Thermosphere Ionosphere Storm Observatory (TISO)
- Tropical Atmosphere/Ionosphere/Thermosphere (TRAIT) Coupler
- UV Spectro-Coronagraphic Observations of Solar Energetic Particle Related Phenomena

Armada



Science Objectives:

- Develop an understanding of the global ionospheric, thermospheric, and plasmaspheric dynamics.
- Understand how high-latitude heating during storms and solar flares affects the global atmospheric structure and dynamics.
- Understand how forcing from the lower atmosphere affects the thermospheric structure.
- Understand how waves and the neutral winds redistribute energy throughout the global thermosphere.
- Understand the global plasmaspheric structure and dynamics during quite and active time periods.

Associated RFAs:

F2.2, F2.4, F3.1, F3.3, F3.5, H2.1, H2.3, H3.2, J1.1, J4.3

Mission Implementation Description:

- **Number of spacecraft:** 25-100
- **Location:** The orbit needs to be started around 500 km altitude and is expected to degrade over ~1-2 years. Orbits can be relatively random, from high to low inclination.
- **Attitude control:** Need to make sure that GPS antenna is pointing roughly up and comm antenna is pointing roughly down.
- **Instrumentation:** Dual frequency GPS using civilian bands.
- **Payload resources:** There is significant flexibility in the launching of Armada. This can be done in a staged cluster deployment over a long time period (1-2 years), utilizing free space on various launchers or small launch vehicles.

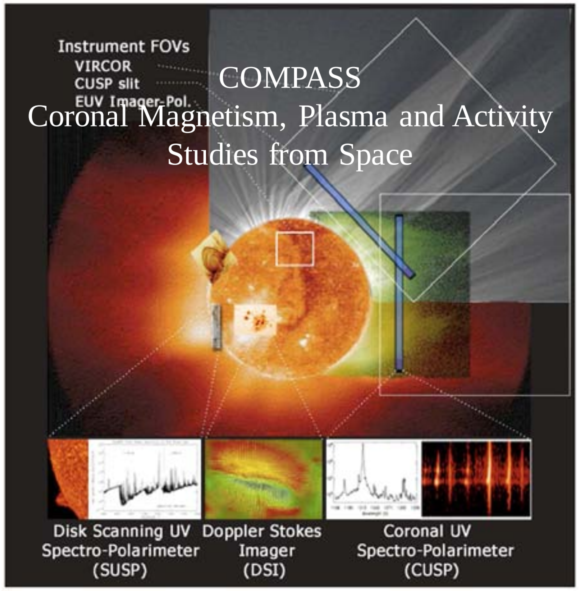
Measurement Strategy:

- We will utilize high-resolution GPS measurements to determine the acceleration and drag on each satellite to infer the thermospheric mass density at each satellite location. The dual-frequency measurements will provide slant-path TEC above the satellites. The use of data assimilation within global ionosphere-thermosphere models will allow specification of the global mass density. The time-history of this (within the model) will allow determination of the neutral winds and other quantities.

Enabling and Enhancing Technology Development:

- No “Enabling” technology required.
- Multiple, identical spacecraft will benefit from streamlined fabrication, test, and management approach.
- Communicating with 100 satellites will involve a distributed array of (low cost) ground-based systems. This can be done with amateur radio groups within universities around the world.
- Determining launches for 100 satellite will involve some planning and clustering of satellites.

Coronal Magnetism, Plasma and Activity Studies from Space



Science Objectives:

- Determine magnetic structure of corona and the connection to magnetic fields in the photosphere via direct measurement
- Understand the nature of changes in the global coronal magnetic field over the solar cycle
- Understand the role of magnetic reconnection in CME formation
- Identify CME shocks in the corona

Associated RFAs:

F1, F2, H1, J2

Mission Implementation Description:

- Atlas launch vehicle. Two formation flying spacecraft in a halo orbit around Earth-Sun L1. 3-axis stabilized sun-pointing, Solar array powered.
- **On-Disk FOV:** Scanning UV Spectro-Polarimeter, EUV Imaging-Polarimeter, Doppler Stokes Imager
- **Off-Disk FOV:** Coronal UV Spectro-polarimeter, Visible & IR Coronagraphic Spectro-polarimater
- **Payload mass:** 260 kg, Power: 1 kW, Telemetry: 900 kbps/ 78 Gbit/day

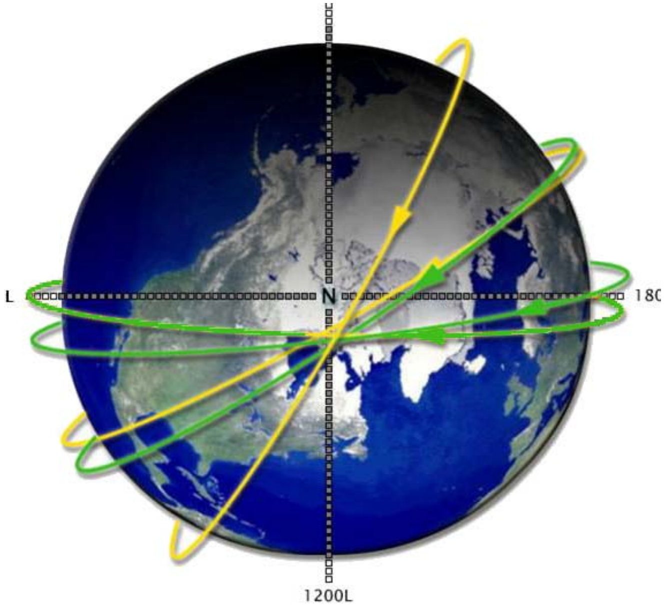
Technology Development:

- Formation flying S/C require development of active formation control, relative navigation, and orbit control optimization
- Payload can be accomplished with minimal new technology

Measurement Strategy:

- Provide measurements in the FUV/EUV of the magnetic field in the outer layers of the solar atmosphere (chromosphere, transition region and corona) by recording the Hanle effect, caused by quantum mechanical interference that influences the polarization of spectral lines, as well as the Zeeman effect in different wavelength bands.
- A visible-light magnetograph will provide the magnetic field at the lower boundary of the atmosphere.
- Observe highly ionized spectral lines in the infrared (IR) solar spectrum and White light images in order to get a complementary picture of the field.
- Sample plasma and the embedded magnetic field at a range of heights and temperatures by measurements in multiple spectral lines on and off the solar disk by combining EUV imaging of coronal plasma with FUV spectro-polarimetry,

Dynamics of the Global Ionosphere -Thermosphere System (DyGITS)



Science Objectives:

- Characterize dynamics of global I-T system
- Understand how system is driven by lower atmosphere and magnetosphere
  - Quantify total I-T energy budget
  - Model substorms, reconnection, and cusp processes
- Characterize electron and neutral density profiles
- Predict ionospheric irregularities
- Measure Poynting and particle energy fluxes

Associated RFAs:

F, H, J

Mission Implementation Description:

- Polar orbits at ~ 600 - 900 km
- Fixed LT at 12:00 and 21:00 MLT
- Two 3-axis stabilized spacecraft

Technology Development:

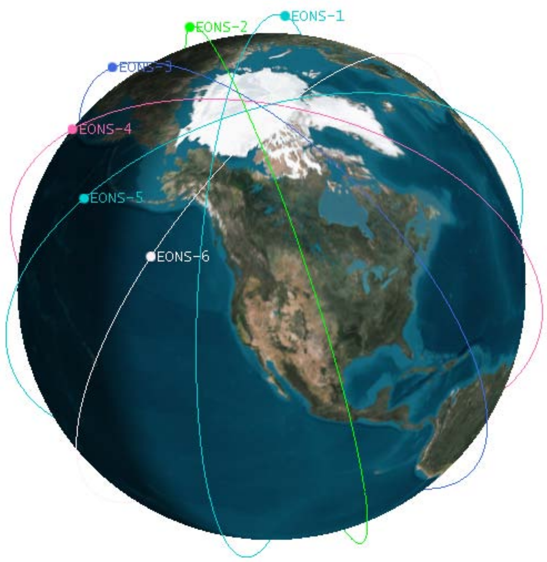
- Mini-satellites launched on ESPA ring with DMSP F20
- Smaller, lighter, low power sensors
- Testbed for plug and play technologies

Measurement Strategy:

In-Situ and Remote-Sensing Instruments

- Mini-UV Spectrograph / Imager
- Thermal Plasma Suite
- Magnetometer
- Energetic Particle Detectors
- DORIS Receiver
- GPS Receiver

Electrodynamics Observations with Numerous Satellites (EONS)



Science Objective:

- To determine when and how the upper atmosphere is driven from below, when and how it is driven from above

Science Questions:

- What are the roles of the disturbance dynamo, tidal dynamos and magnetospheric penetration electric fields in determining the global electrodynamics at?
- How does the coupling between ion and neutrals affect the structure of the upper atmosphere?

Associated RFAs:

F2, F3, F4, H2, H3, H4, J1, J2, J4

Mission Implementation Description:

- 6 small-sats in 450 km circular orbits, final configuration separated by 2 hours LT
- 3-axis stabilized; eclipse operations
- 5 in-situ instruments (TRL-9), 1 remote sensing (TRL 7)
- Payload resources req'd (each sat.): 16kg, 40W, 12kbps

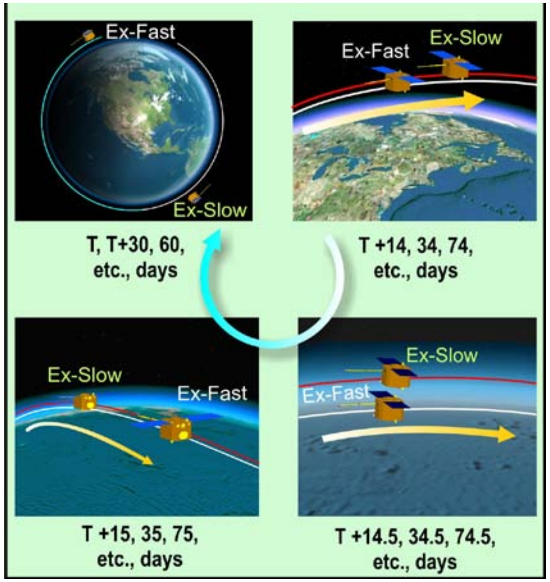
Measurement Strategy: Three Mission Phases

- **Phase 1:** Pearls on a string - all 6 satellites are deposited into the same orbital plane at 600 km.
- **Phase 2:** Slowly phasing – sequential satellite drops to 450 km after certain months - space satellites out in LT
- **Phase 3:** Final configuration - Spread out equally in local time at the same altitude in 6 orbital planes

Enabling and Enhancing Technology Development:

- Small satellite technology with 3-axis stabilization
- Next generation GPS receivers
  - Optimized for small satellites
  - Capable of using Galileo constellation
- Ion thrusters optimized for small satellites would enhance maneuverability/lifetime

Explorer of Coupled Ionosphere Thermosphere Electrodynamics (ExCITE)



Science Objectives:

- In response to magnetospheric and solar inputs the ionosphere and thermosphere respond as a non-linear coupled system. A characteristic of all non-linear systems is the possession of a memory for previous inputs.

Compelling Question:

- What is the memory time-constant for key ionosphere-thermosphere variables over different spatial scales?

Challenge:

- Present specification of ALL external drivers to the ionosphere-thermosphere system does not determine the present state of the system

Associated RFAs:

F3, H2, J4

Mission Implementation Description:

- **Number of spacecraft:** 2 (or more incrementally)
- **Location:** LEO 400 KM circular
- **Attitude control:** 3-axis stabilized (1 rev per orbit)
- **Number of instruments:** 4-5
- **Type of instrument(s):** in-situ/remote ion/neutral drifts, ion/neutral composition energetic particles, magnetic field
- **Payload resources required:** 115 kg, 100W, 9kbps per spacecraft

Measurement Strategy:

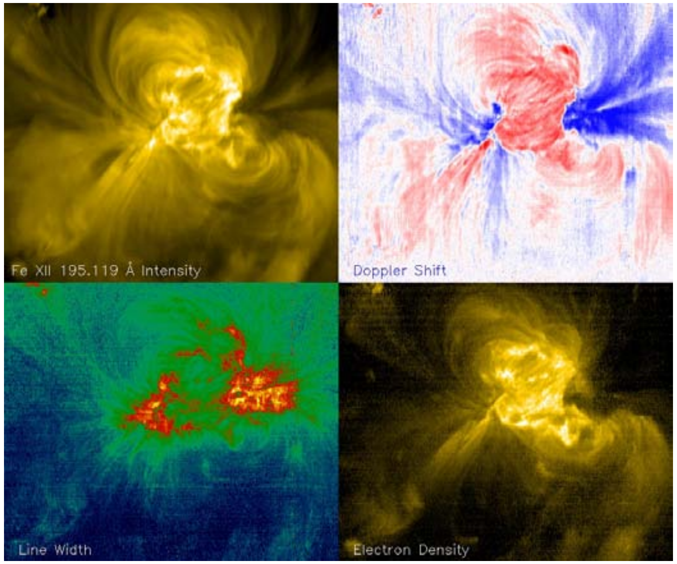
- Small spacecraft with key measurement capability only.
- Evolution of density and dynamics signatures identified with variable spacing through the same volume.
- Small differences in orbit periods allow time spacing from zero to 1/2-orbit period.
- Simple cold-gas propulsion for drag make-up and orbit period adjustments.
- High inclination provides longitude and local time coverage in less than 2 months.

Enabling and Enhancing Technology Development:

- UV imaging with high spatial/temporal resolution

Fine-scale Advanced Coronal Transition-region Spectrograph (FACTS)

FACTS will make measurements of the upper solar atmosphere with factor of ~10 better spatial resolution and larger aperture than prior UV instruments.



EIS/*Hinode* measures intensity, Doppler shift, line width and density.

Science Objectives:

- Determine and characterize the dominant physical processes responsible for the structure,dynamics and evolution of the upper solar atmosphere. These processes drive the global flow of mass/energy in the outer solar atmosphere and space weather events.
- Observations: FACTS makes rapid, naturally co-aligned spectroscopic measurements from the photosphere to the corona with 0.1" UV spatial resolution. This combination of temperature coverage and matching spatial resolution has never been achieved before.

Most relevant RFAs:

F1: Understand magnetic reconnection … flares, CMEs, …;
F2: Understand processes … that accelerate … particles;
H1: Understand causes…solar activity ... that affects earth;
J2: Develop prediction capability of … solar activity…

Mission Implementation Description:

- **Mission:** single spacecraft mission, 3 axis stabilized, 24 hour solar viewing for most of the year.
- **FACTS instrument:** 0.1" resolution, four channel EUV/Vis (nominal 170-210Å, 500-2000Å, 2000-8000Å) spectrograph, UV/Vis filter imager.
- **EUV spectral imager:** 0.1", four channels.
- **Estimated payload resources required:** ~200-250kg, 120W,1-5Mbps daily average TM rate, payload TRL 7.

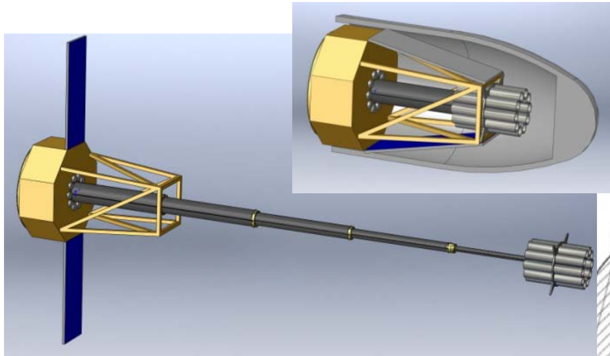
Measurement Strategy:

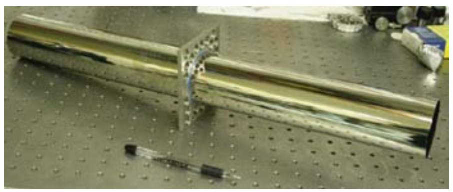
- rapid, high spatial resolution, spectra observations.
- simultaneous, coaligned EUV to Vis spectra.
- context provided by: coarser resolution rasters, UV/Vis filtergraph, high resolution EUV spectral imager.

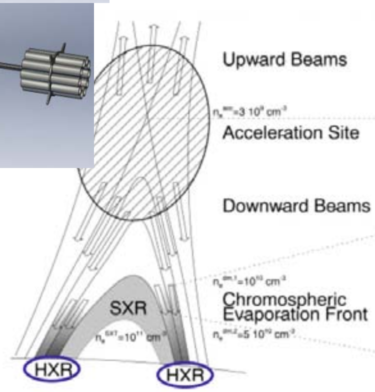
Enabling/Enhancing Technology Development:

- Light weight mirror technologies and LOS stabilization systems for half meter class optics.
- Efficiency and space/solar-flux durability improvements of EUV optical coatings.
- High speed, small pixel, low noise, EUV and visible sensitive rad hard detectors (especially active pixel sensors and solar blind EUV detectors).
- High quality, EUV ellipsoidal variable line spaced gratings.
- Improvements (cost and performance) of spacecraft ACS and TM (e.g. transmitters, receivers, ground stations, reaction wheels, star trackers, sun sensors).

Focusing Optics X-ray Solar Imager (FOXSI)







Science Objectives:

1. Flare Acceleration Region - FOXSI will be able to image where electrons are accelerated, along which field line they travel away from the acceleration site, where they are stopped, and how some electrons escape into interplanetary space.
2. CMEs - High sensitivity HXR observations by FOXSI will enable direct observations of electrons accelerated by CMEs as they travel in the low corona.
3. Radio Emission - FOXSI will allow for the detection HXR emission from electrons that produce coherent radio bursts for the first time.
4. Other targets also include microflares, the Quiet Sun, Solar Axions, and astrophysical sources

Mission Implementation Description:

- Single 3-axis stabilized spacecraft in Earth orbit.
- **Total weight:** 250 kg
- **Power req:** 50 W.
- **Sensitivity:** 100x RHESSI.

Focal Plane Detectors

- Si pixel detectors.
- CZT pixel detectors.
- based on NeXT mission.

Optics

- Based on HERO optics (Ramsey et al.)
- Grazing incidence hard x-ray mirrors.
- Field of View of 700 x 700 arcsecs.
- Effective area 150 cm^2 up to 50 keV (4x RHESSI) or 1 cm^2 per kg of optics.
- Spatial resolution of of single shell 7’ arcsec FWHM.

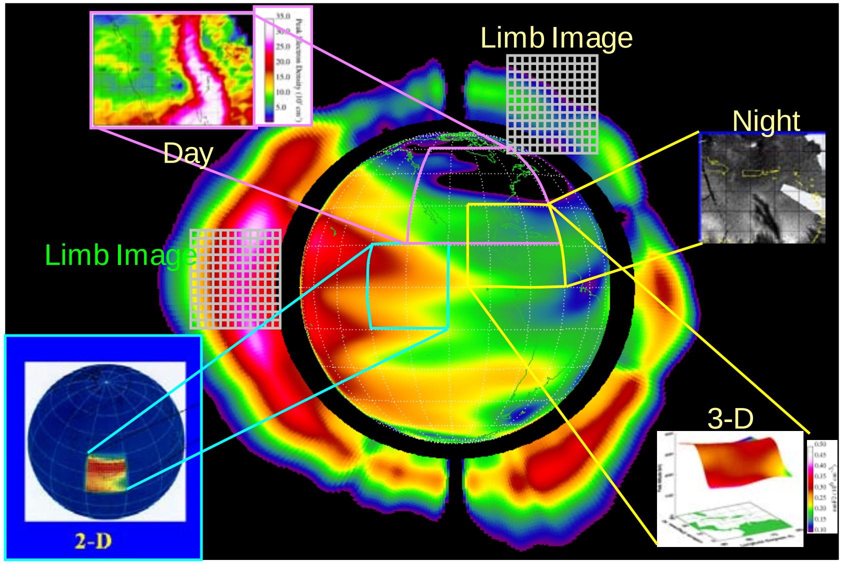
Associated RFAs:

F1, F2, H1

Enabling and Enhancing Technology

- CZT and Si pixelated detectors - Developed for NeXT, currently are strip detectors with 100 um (Si), 200 um (CZT) strip size. New smaller ASIC will do single pixel readout and
- HXR Focusing Optics - Based on HERO, new processes in nesting shells and coating deposition will increase the maximum spatial resolution.

FUV and EUV Imaging of the Thermosphere and Ionosphere from GEO



Day & Night Imaging of the Limb & Disk from GEO: O/N$_2$ & Ionosphere

Science Objectives:

- What is the prompt global-scale ionospheric response to geomagnetic storms?
- What are the extended responses of the thermosphere and the global scale ionosphere to geomagnetic storms?
- How do traveling ionospheric disturbances develop and propagate?
- What affects the day to day variability of the equatorial ionosphere?
- What are the temporal and spatial properties of high latitude upflows and outflows?

Associated RFAs:

F2, F2, H2, H3, J4.

Mission Implementation Description:

- **Number of Spacecraft:** 1
- **Location:** Geosynchronous
- **Attitude Control:** 3-axis stabilized
- **Number of Instruments:** 1 or 2
- **Type of Instrument(s):** 2 UV Imagers, mostly TRL9
- **Payload Resources Required:** 195 lb, offset pointing

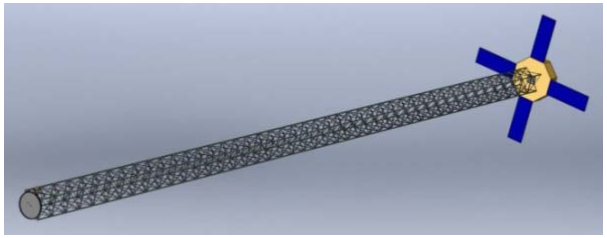
Measurement Strategy:

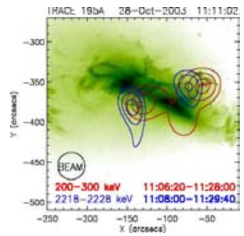
- FUV/EUV Imagery at 10 km resolution (best case)

Enabling and Enhancing Technology Developments:

- High performance reflective filters for UV
- High performance microchannel-plate based detector systems
- Newly developed algorithms for inverting the UV radiances to produce neutral and ion densities
- Low cost, frequent access to GEO (presently limited to finding missions of opportunity, which are chiefly on communications satellites)

Gamma-Ray Imager/ Polarimeter for Solar Flares (GRIPS)





Solar flares accelerate both ions and electrons to high energies. Accelerated ions produce gamma-ray lines through nuclear interactions that reflect the nature and location of their acceleration. Relativistic electrons accelerated in solar flares produce polarized bremsstrahlung emission depending on their angular distribution.

Images from *RHESSI* (e.g., Hurford et al. 2006) indicate that accelerated ions are interacting in localized regions that are spatially shifted from the locations of accelerated-electron interactions.

GRIPS Fundamental Goal:

- Understand energy release at the Sun and its effect on Earth and the solar system by studying particle acceleration associated with solar flares
- Science Objectives:
- Determine the spatial distribution of flare-accelerated ions and electrons
- Determine the angular distribution of relativistic electrons
- Study the trapping of relativistic electrons in flare loops
- Determine the accelerated-ion spectrum and associated elemental abundances

Associated RFAs:

F2, H1, J2

Mission Implementation Description:

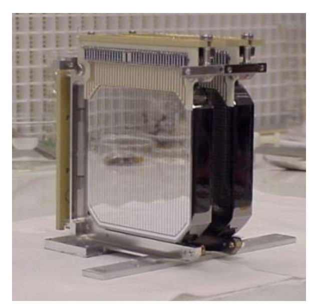
- One spacecraft in a near-equatorial, ~600-km low-Earth orbit
- Three-axis stabilized, mass: 190 kg, power: 340 W, data: 4 GB/day
- **Imaging:** angular resolution of ~5 to 100s of arcseconds
- **Polarization:** ~1% minimum detectable polarization at 150–650 keV
- **Spectroscopy:** 3 keV to 17 MeV, resolution of 1.8 keV at 662 keV
- **3D spatially resolving germanium detectors (3D-GeDs):** excellent spectral resolution
- **Single-grid tungsten Multi-Pitch Rotating Modulator (MPRM):** provides a point-response function virtually free from sidelobes
- 20-meter extendable boom separates MRPM and spectrometer for imaging technique, with loose requirements on twist and stability
- Compton-scatter reconstruction techniques used to determine the polarization of incident photons and to provide background rejection

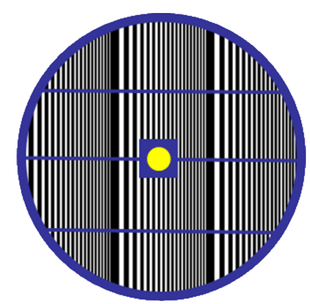
Measurement Strategy:

- Perform a combination of imaging, spectroscopy, and polarimetry of gamma-ray line sources and X-ray sources

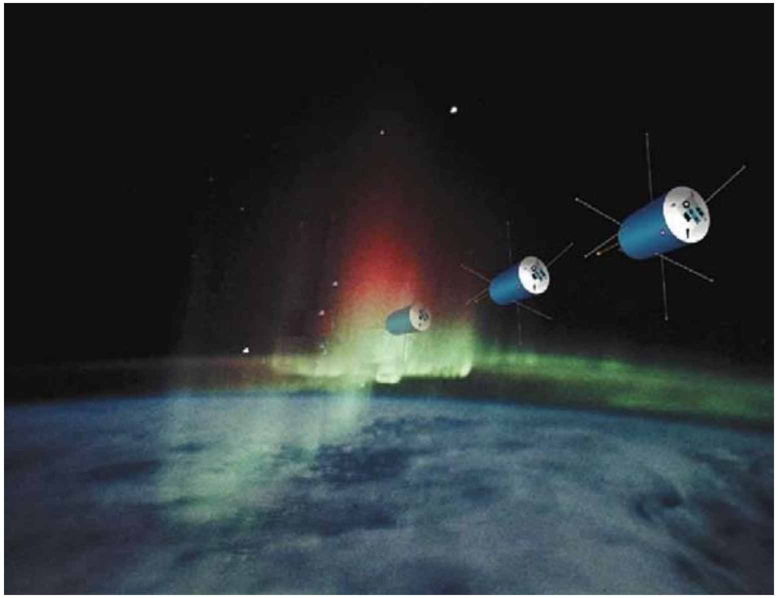
Enabling and Enhancing Technology Development:

- Currently funded NASA Low Cost Access to Space balloon version of GRIPS will prove these technologies:
  - 3D-GeDs with 0.5-mm strip pitch — detectors with coarser pitch have been built and flown on NCT balloon payloads
  - Multi-Pitch Rotating Modulator grid — simple to fabricate and tungsten grids have been used on RHESSI and HEIDI
- 20-meter boom — already developed for other space missions





Geospace Electrodynamic Connections (GEC)



Science Objectives:

- Understand how the ionosphere-upper atmosphere is controlled by magnetosphere forcing
- Determine how the magnetosphere responds to the dynamics of the ionosphere-upper atmosphere

Associated RFAs:

F3, H2, J4

Mission Implementation Description:

- Multiple spacecraft, pearls-on-a-string configuration.
- 185 X 2,000 km; 83° inclination parking orbit; at times, lower perigee to an altitude of ~ 130 km for ~one week.
- 3-axis stabilized
- 8 identical instruments on each spacecraft
- All in situ measuring instruments, TRL-levels 8-9
- Each s/c: ~600 kg dry mass; ~300 watts; ~11Gbits/day

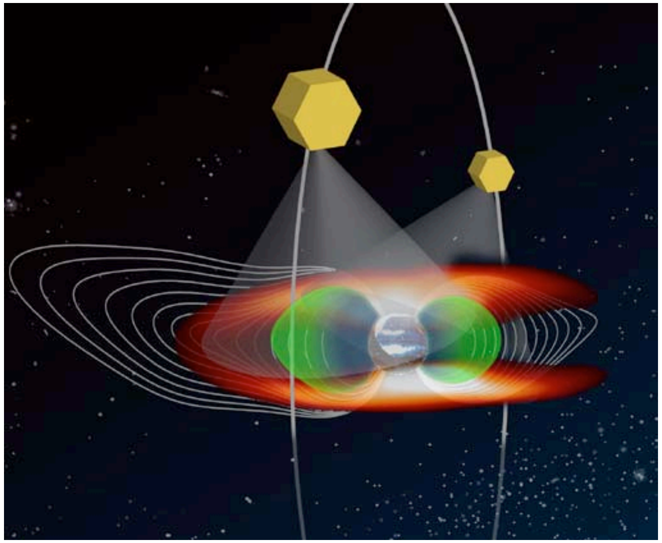
Measurement Strategy:

- Measure all plasma-neutral coupling physics parameters
- Sample high latitudes where magnetosphere- ionosphere coupling is greatest
- Variable inter-spacecraft spacing to resolve different scales
- Deep dips to where atmosphere begins to dominate the plasma dynamics

Enabling and Enhancing Technology Development:

- Low cost s/c bus.

Geospace Magnetospheric and Ionospheric Neutral Imager (GEMINI)



GEMINI seeks to understand terrestrial space weather as one coupled system by simultaneously imaging the magnetosphere and ionosphere.

GEMINI Goal

- Understand the cause and evolution of space weather storms in the magnetosphere-ionosphere system

Science Objectives

- Visualize the simultaneous 3D evolution of magnetospheric and Ionospheric plasma
- Determine the causes and impacts of the explosive growth of plasma pressure in the magnetosphere
- Determine how the global electric field controls transport of plasma throughout the system
- Determine the global variability of the magnetic field in the inner magnetosphere
- Determine the spatial and temporal evolution of the overlap of hot and cold plasma critical for global wave activity

Associated RFAs

F1, F2, F3, H1, H2, H4, J1, J4

Measurement Strategy

- Image the 3D distribution and evolution of the two most important populations in the magnetosphere:
  - the ion plasma pressure using energetic neutral atoms (ENA) with sufficient temporal and spatial resolution to retrieve the electrical current system that distorts the magnetic field and that connects through the ionosphere producing the electric field
  - the plasma sphere using extreme ultraviolet (EUV) with sufficient temporal and spatial resolution to retrieve response to the electric field
- Image the ionosphere using
  - multiple wavelengths of far ultraviolet (FUV) to assess auroral energy input and ionospheric-thermospheric composition changes and transport
  - multiple radars to image the plasma flow and electron density profiles in order to estimate the ionospheric electric field and constrain conductance

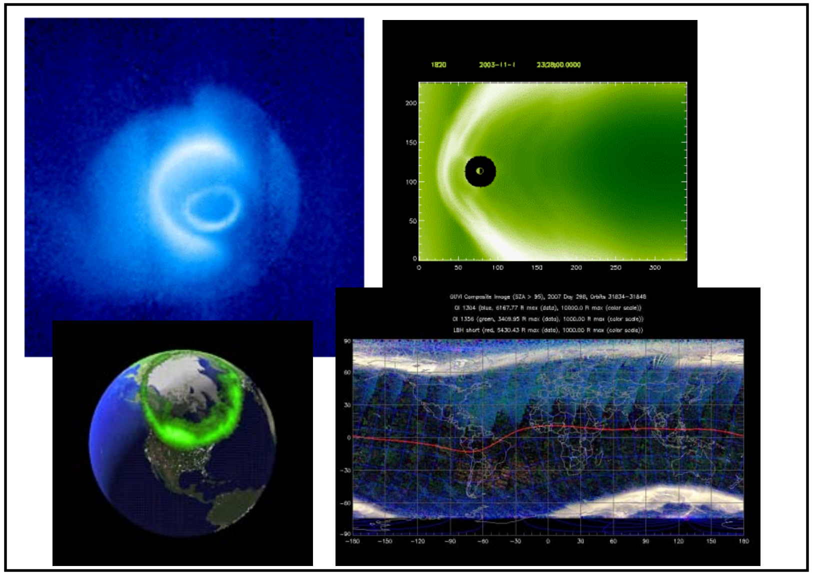
Mission Description

- Two High Altitude Spacecraft in ~8RE circular near-polar orbit
  - 1 ENA, 1 EUV, 3 FUV cameras per S/C
  - nadir pointing with yaw about nadir
- Ground-based radar network to cover the mid- to high-latitude ionosphere (occasional equatorial coverage preferred)
- 2 year life time

Enabling Technology Development

- None

Geospace Observer from Large Distance (GOLD)



Science Objectives:

- Understand the dynamic coupling of the magnetospheric system to solar wind variations
- Understand the evolution of the ionosphere in response to the magnetospheric driver
- Understand critical global parameters and dynamics that drive physical prediction models

Associated RFAs:

F1, H2, J1

Mission Implementation Description:

- Single spacecraft to image the magnetosphere, the plasmasphere, and the ionosphere
- **Location:** Lunar orbit (Other possiblities include L1, heliocentric Earth synchronous)
- **Attitude Control:** 3-axis stabilized
- **Instruments:** (all Imaging)
  - Magnetospheric Imaging Coronagraph (MAGIC)
  - Magnetotail Reconnection Imaging Exp (MATRIX)
  - Plamaspheric Imaging Experiment (PIXI)
  - Ionospheric Imager (II)
- **Payload resources required:** (100 kg/80 W/250 kbps)

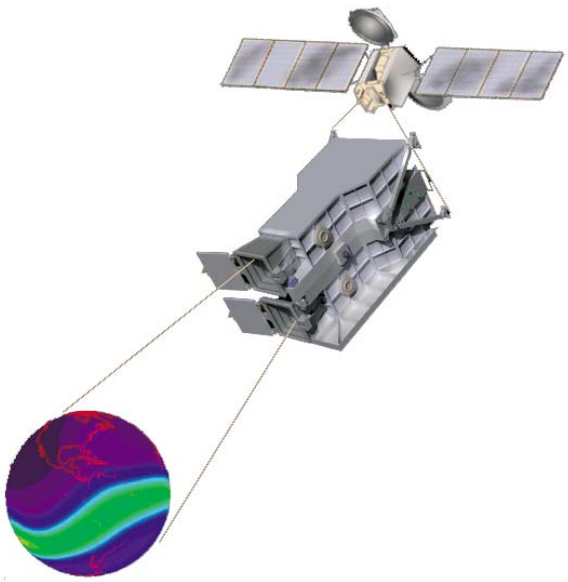
Measurement Strategy:

- Images obtained 1/min at a resolution of 1000 km to reveal global magnetospheric structure

Enabling Technology Development:

- No enabling technology necessary
- Enhancing Technology Development:
- Lightweight advanced baffle design
- High-performance computing on board, or large continuous data downlink
- Lightweight optics

Global-scale Observations of the Limb and Disk (GOLD)



Science Objectives:

- Understand how geomagnetic storms alter the thermosphere and the low-latitude, nighttime ionosphere
- Quantify the global-scale response of the thermosphere to solar extreme-ultraviolet variability
- Determine whether atmospheric waves and tides have a significant effect on thermospheric temperature structure
- Quantify how vertical ion drifts, as manifested in the structure of the equatorial anomaly, affect the occurrence of ionospheric irregularities

Associated RFAs:

F3, H2, H3, J4

Mission Implementation Description:

- **Number of spacecraft:** 1
- **Location:** Geostationary
- Flight on commercial communications satellites
- **Number of instruments:** 1
- **Type of instrument:** remote, TRL-level: 6 or greater
- **Payload resources required:** (30 kg/30 W/5.0 Mbps)

Measurement Strategy:

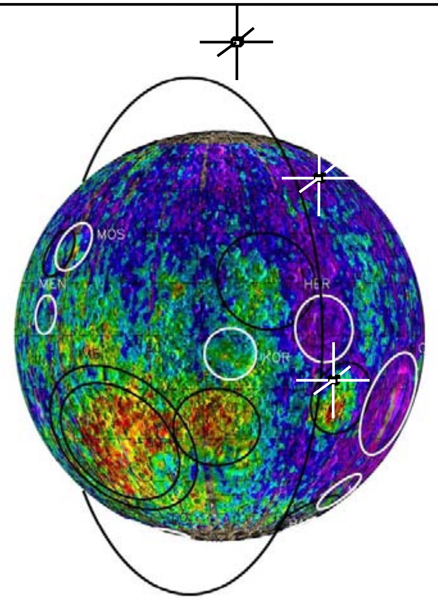
- Simultaneous disk images of daytime Tn and O/N_2 ratio
- Disk images of peak electron densities and low latitude irregularities at night
- Limb measurements of O_2 density profiles and Texo

Enabling and Enhancing Technology Development:

- Enabling Technology
- Inexpensive access to geostationary orbits
- Enhancing technology
- Solar irradiance and solar wind measurements

Heliophysical Plasma Physics In Lunar Orbit (HILO)

HILO



Science Objectives:

To understand the:

- Fundamental physics of plasma interactions with magnetic fields from kinetic (particle) to fluid behavior, using lunar magnetic anomalies of a few km to ~100s of km size – from less to greater than thermal proton gyro-diameter.
- Ion & electron decoupling from the magnetic field.
- Formation of (mini-) magnetospheres & shocks (for super-Alfvenic flow)
- Dynamics of the Earth's distant (>~60 Re) magnetotail & reconnection, using lunar shadowing of electrons to determine the topology of magnetic fields & their velocity.

Mission Implementation:

- Multiple spin-stabilized spacecraft in lunar polar orbit with ~10 km periselene altitude and variable separations
- **Measurements:** fast 3D ion & electron plasma, magnetic & electric fields, plasma & radio waves, suprathermal particles, EM sounder for electron density tomography
- **Instruments:** in situ in addition to remote sounder & radio waves, all TRL-6 or higher
- **Payload resources required:** ~30kg, ~30 W, ~4kbps

Measurement strategy:

- High time resolution burst mode in regions of interest; store & dump data to ground

Associated RFAs:

F1. Understand magnetic reconnection

F2. Understand plasma processes that accelerate & transport particles.

F3. Understand plasma and neutral interactions

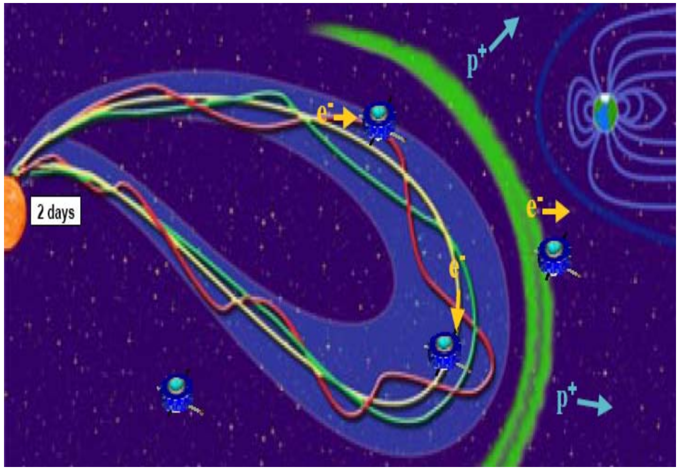
H4. Apply space plasma physics to magnetic shielding

J1. Characterize the space environments

Enabling and Enhancing Technology Development:

- EM sounder technology for distance determination.
- Study of flight dynamics for low altitude lunar orbit.
- Study of electron density tomography

Heliosphere Explorer (HELIX)



Left: RHESSI/TRACE observations of gamma-ray line (blue) & hard X-ray continuum (red) footpoints straddling the flare loops, revealing both ion & electron acceleration related to reconnection.
Right: HINODE XRT image sequence showing evidence of magnetic reconnection.

Science Objectives

- To explore the inner heliosphere, where the most energetic and dynamic phenomena in the solar system take place, and answer these questions.
- How and where are solar energetic particles (SEPs) accelerated?
- What is the origin of CMEs, how are they related to solar flares?
- What is the structure and topology of the magnetic field from the corona to the inner heliosphere ,and how does it evolve?
- What are the physical processes that accelerate the slow solar wind?
- What are the conditions in the inner heliosphere that affect Space Weather?

Observational Objectives

- Trace the magnetic structure of the solar corona and heliosphere.
- Address the critical issues in Solar Energetic Particle (SEP) acceleration,
- Identify solar wind sources.
- Trace the origin, propagation, and interactions of CMEs
- Probe solar wind plasma microphysics in the inner heliosphere,

Mission Implementation

- HELIX utilizes multiple small spacecraft in inner heliosphere orbits to provide multi-point in situ and remote measurements. The multiple spacecraft are launched by a single rocket to encounter Venus, where gravity assists are used to obtain the needed spread of orbits. The spacecraft are spin-stabilized, and carry in situ particles and fields plus simple remote sensing instruments that utilize spin-scanning plus multi-spacecraft occultation and directivity.
- **Total payload resources (each spacecraft):** ~25kg / ~25 W / ~10 MB per day
  - Operation during solar activity maximum ~2020

Instrument Payload

- Solar wind ions & electrons; suprathermal ions & electrons; solar wind & suprathermal composition & charge state; energetic ions, electrons, gamma-rays & neutrons, magnetometer, radio & plasma waves, X-rays.

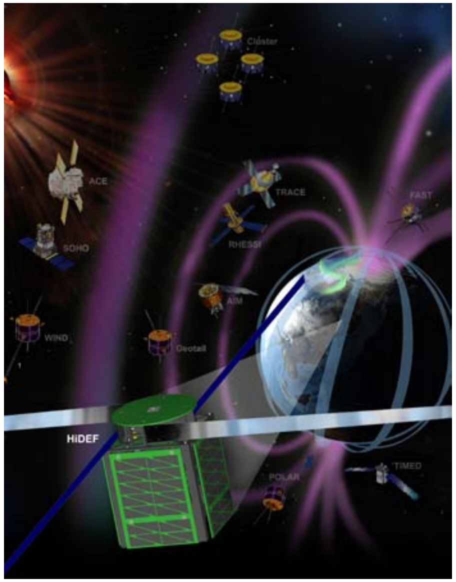
Associated RFAs:

F1, F2, H1, J2, J3

Key Measurements & Candidate Instruments

- Solar wind ions, 0.1-20 keV/q, Solar wind electrons, 1 eV-5 keV
- Solar wind & suprathermal ions, composition & charge state, ~ 2-160 keV/q
- Suprathermal Z>~2 ion composition, ~5 keV-2MeV/nucleon
- Suprathermal & energetic electrons, 2 keV to ~5MeV
- Energetic protons, 20 keV – 7 MeV
- Energetic ions, elemental composition, 2- 100 MeV/nuc
- Neutrons, 0.5 – 20 MeV
- Gamma-rays, 0.3 – 8 MeV
- Vector magnetic fields
- Radio & plasma waves, few Hz - 16 MHz
- Soft & hard X-ray spin-scan imaging, ~2-100 keV

High-latitude Dynamic E-Field Explorer (HiDEF)



Science Objectives:

- HiDEF will observe and resolve the inadequately understood high-altitude magnetosphere-ionosphere-thermosphere global electric field forcing, coupling dynamics, and evolution over a wide range of spatial and temporal scales, providing the last major link in the Earth-Sun connection.

Associated RFAs:

F3, H2

Mission Implementation Description:

- 90 satellite constellation (20% redundancy)
- **Location:** Low Earth Orbit (515-675 km)
- **Attitude control:** spin stabilized
- Electric field sensor – measures in-situ DC and AC components
- TRL 8/9
- Mass- 1.08 kg/spacecraft, Power – 0.82 W avg/spacecraft, Telemetry- 619 Mb/constellation

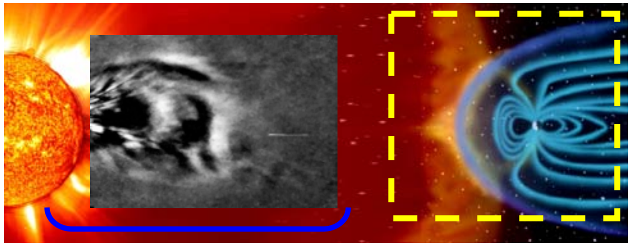
Measurement Strategy:

- Global ionospheric electric field measurements

Enabling and Enhancing Technology Development:

- Picosatellite constellation (global science platform)
- Miniaturized science payload, communications hardware, and attitude sensors
- Advanced tracking and ground station coordination

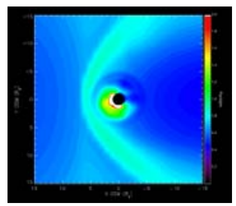
Imaging Geospace Electrons Using Thomson Scattering



We can observe disruptive solar events such as CMEs from the Sun through the heliosphere.

Thomson scattering observations of geospace electrons will complete our chain of Sun-to-Earth observations, enabling global specification and forecasts of the ionosphere-plasmasphere-magnetosphere system in response to solar drivers.

Simulated Thomson scattering images of geospace electrons (right, no noise), show the bow shock, magnetosheath, magnetopause, and the plasmasphere in a SAMI3-LFM model scene.



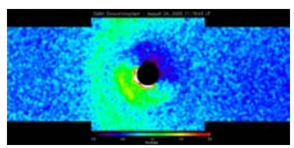
Science Objectives:

- Determine how electrons in the magnetosphere, plasmasphere, and ionosphere are redistributed in response to solar wind forcing
- Understand mechanisms of solar wind plasma entry into the magnetosphere by globally imaging structures along the magnetopause and magnetospheric boundary layers

Associated RFAs

H2, J4

Mission Implementation Description:



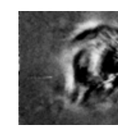
- One 3-axis stabilized spacecraft
- 30-R_E circular, inertial polar orbit
- Four imagers (two “geo-coronagraphs”, two white-light, magnetospheric imagers). Simulated image with noise shown above, right
- Payload mass estimate (instruments and spacecraft): ~1700 kg

Measurement Strategy:

- Observe Thomson scattered light to directly image geospace electron densities and their interactions with the solar wind

Enabling and Enhancing Technology Development:

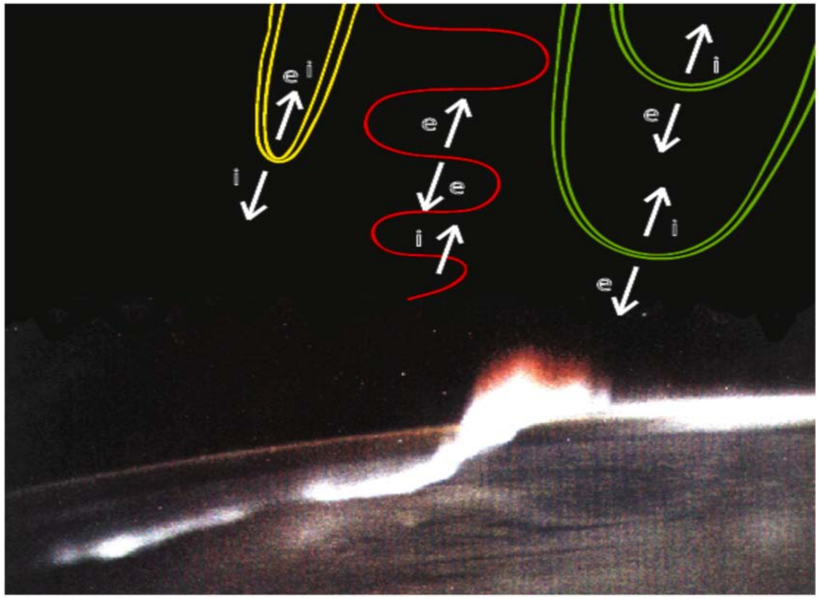
- NASA-sponsored coronagraphs and STEREO SECCHI/Heliospheric Imagers have successfully imaged structures in the solar wind (CMEs and CIRs) by observing Thomson scattered light. Leveraging NRL expertise, we will adapt these techniques to directly image geospace electrons for the first time.



Other enabling technologies required for this mission:

- Large format focal plane detector arrays and light-weight optics
- Formation flying satellites (potentially)
- Next generation space environment forecasting models that couple all regions of geospace including the bow shock, magnetosheath, and magnetopause

In-situ Diagnostics of Universal Plasma Processes



Science Objective:

- To use the Earth's local plasma laboratory to diagnose universal plasma processes

Processes to study:

- Alfvén waves, double layers, electron and ion phase space holes, two stream instabilities, AKR-radiation, pitch angle scattering, surface waves, filamenation, flow shears, Langmuir waves, etc.

Problems to solve:

- Resolve spatial and temporal ambiguities in plasma processes
- Understand plasma dynamics and evolution
- Understand how processes of different scale sizes interact with each other

Mission Implementation Description:

- **Number of spacecraft:** 2
- **Attitude control:** Spin stabilized
- **Orbit:** 350 x 5000 km , Incl. 80°
- **Orbit phase 1:** String of pearls
- **Orbit phase 2:** Magnetic conjunctions
- Each satellite has full complement of fields- and particle- sensors and imagers (in-situ and remote)
- **Payload resources required (per spacecraft):** Mass 75 kg, Power 45 W, Telemetry 2.0 Mbps
- Science team with Astrophysical and Plasma physics expertise

Associated RFAs:

F2, F3

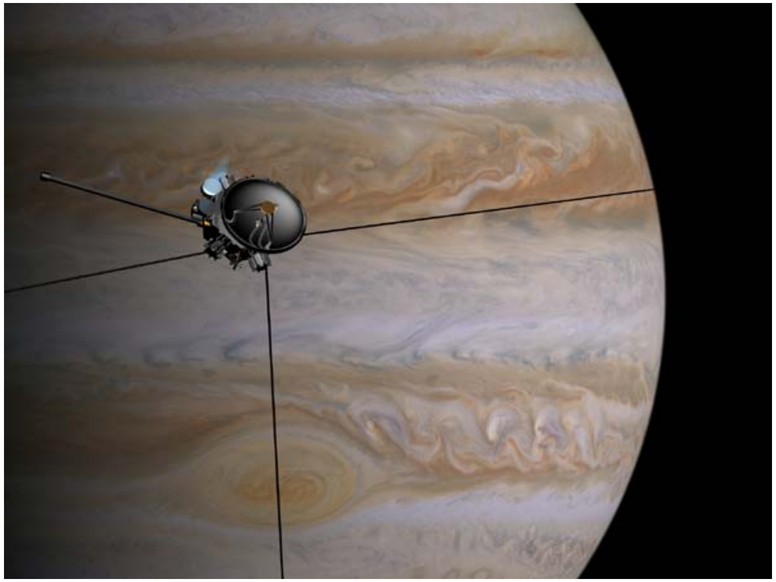
Measurement Strategy:

- High temporal resolution plasma measurements with high spatial and temporal imaging
- Large satellite memory allowing interesting data periods to be selected for downloading
- Integrated sensors for optimal operation and science return

Enabling and Enhancing Technology Development:

- Robust, in-expensive, light weight, de-spun imager

Interstellar Explorer – An Interstellar Precursor Mission



Science Objectives:

- Explore the influence of the interstellar medium on the Solar System, its dynamics, and its evolution*
- Explore the impact of the solar system on the interstellar medium as an example of the interaction of a stellar system with its environment*
- Explore the outer Solar System in search of clues to its origin, and to the nature of other planetary systems*

**From NASA's Interstellar Probe STDT Report*

Associated RFAs:

F2, F3, H4, J1, J3

Mission Implementation Description:

- **Number of spacecraft:** 1
- **Location:** Deep space; solar system escape
- **Attitude control:** Spin stabilized
- **Number of instruments:** 10
- **Type of instrument(s):** 7 in situ, 3 remote, TRL 5-8
- **Payload resources required:** 47 kg, 40 W, 7.8 kbps (~35% margins)

Measurement Strategy:

- Slow sky scans with spin stabilization; store and dump to Earth periodically (two 8-hr downlinks per week) over 30 years

Enabling and Enhancing Technology Development:

Enabling:

- High efficiency, low-specific-mass Stirling radioisotope generators
- Radioisotope electric propulsion (REP)
- Low-mass, low-power instruments

Enhancing:

- Ares V launch vehicle with Centaur upper stage or NERVA-derivative nuclear upper stage
- TRL-9 400m+ dia solar sail with areal density not to exceed 1 g m-2

I-T Constellation

Science Objectives:

- Determine and understand the coupled state of neutral and ionized gases in the ionosphere-thermosphere system, including global neutral wind, density, electrodynamic, and gravity wave patterns and variability.
- Determine how the global ionosphere/thermosphere system responds to magnetic storms at all latitudes and local times simultaneously.
- Determine and understand high latitude electrodynamics at all local times and its response to, and coupling with, magnetospheric forcing on time scales commensurate with storm and sub-storm-driven events; Evaluate the global neutral wind and thermal plasma/neutral response to this forcing.

Associated RFAs:

F2.4, F3.1, F3.2, F3.3,F3.5, H2.1, H2.2, H2.3, J1.1, J4.2, J4.3

Mission Implementation Description:

- **Number of spacecraft:** 3 (minimum) to 6 or 12 or ?
- **Location:** 6 “baseline” satellites with 90° inclination flying “in formation” in 6 orbit planes (12 local time planes, like Iridium) in circular orbits at (say) 450 km (1year), 350 km (1 year), with options for elliptical orbits with low perigees
- **Attitude control:** 3-axis stabilized, momentum biased at 1 RPO
- **Instrumentation:** Combination of in situ and remote sensing instrumentation suite. TRL > 8 for all instruments.
- **Payload resources:** 6 s/c launched together (like COSMIC), s/c, propulsion, instruments: ~ 150-350 kg each, (depending on complexity); propulsion used to achieve local time spacing

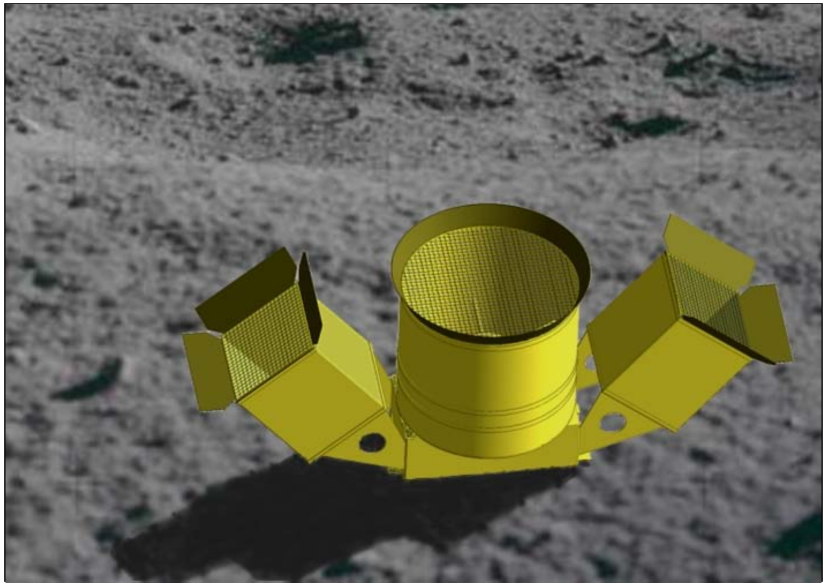
Measurement Strategy:

- Satellites provide global coverage of all key neutral and plasma parameters including in-situ measurements of neutral density, temperature, winds, composition; ion density, drift, temperature, composition; electric and magnetic fields, and energetic particles; remote sensing measurements of gravity waves, airglow, and wind and plasma density profiles along orbit track. A revolutionary and vitally important new view of the global I-T system at all local times and latitudes will be achieved.

Enabling and Enhancing Technology Development:

- No “Enabling” technology required.
- Multiple, identical spacecraft will benefit from streamlined fabrication, test, and management approach as demonstrated and fostered by experience with Cluster, COSMIC, Iridium, and THEMIS, and MMS.
- There is considerable technical and scientific trade space to consider. For example, a more modest approach could include a simpler instrument suite with more limited science measurement goals. Smaller s/c could be launched on separate vehicles to eliminate the need for propulsion.

Lunar Dust Observatory



Science Objectives:

- To investigate the interplanetary and interstellar as well as the local lunar dust environment as function of the solar wind conditions.
- By means of a Dust Telescope the Dust Observatory will (1) provide the distinction between interstellar dust and interplanetary dust of cometary and asteroidal origin, (2) determine the elemental composition of impacting high-speed dust particles, and (3) monitor the fluxes of various dust components as a function of direction and particle masses. In addition it provides the characterization of the local lunar dust environment.

Associated RFAs:

F3-4, H4-4, J1-1

Mission Implementation Description:

- **Number of spacecraft:** Lunar Lander
- **Location:** Lunar surface
- **Attitude control:** Articulation of the Dust Telescope
- **Number of instruments:** suite of > 3 dust analyzers
- **Type of instruments:** in-situ dust analyzers, TRL-level: 4 - 5
- **Payload resources required:** (30 kg, 50 W, 100 kbps)

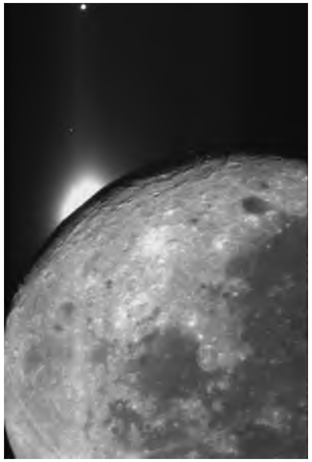
Measurement Strategy:

- Continuous measurement
- Staring observations in various directions

Enabling and Enhancing Technology Development:

- Develop flight instrumentation for dust trajectory measurement and for in-situ chemical analysis of fast moving interstellar and interplanetary dust
- Develop flight instrumentation for the measurement of slow moving electrically charged dust.

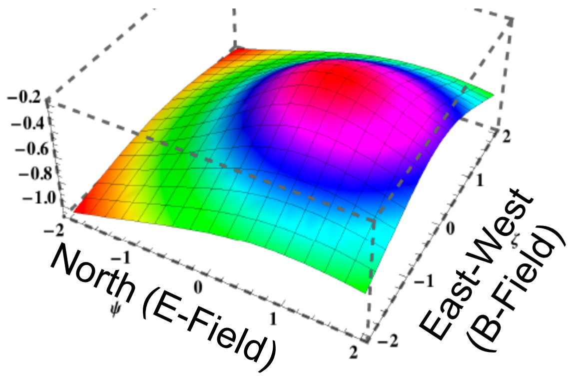
Lunar Surface Solar Origins Explorer (LunaSSOX)



Lunar Limb "Knife-Edge" for solar coronal occultation

Solar Wind Ion Implantation Injects Solar Coronal Composition Into the Lunar Surface and Solar Energetic Ions (SEP) Sputter Surface Atoms

<u>Lunar He^+ Antisolar Pickup Ion Flux</u>



<u>Science Objectives:</u>

- Upstream solar wind plasma ion contributions to lunar surface volatile composition via orbital measurements
- Global distribution of volatile and refractory surface composition via pickup ions from SEP ion sputtering
- Solar F-corona plasma composition & near-solar dust interaction via remote spectroscopic & doppler imaging

<u>Associated Heliophysics RFAs:</u>

F3, J4

<u>Mission Implementation Description:</u>

- **Number of Spacecraft:** 1 or more
- **Location:** lunar 50-km polar orbit, day-night orientation
- **Attitude control:** 3-axis stabilized (ram, nadir, solar)
- **Instruments:**
  - in situ low-energy ion-neutral and energetic heavy ion mass spectrometers , magnetometer (20 kg/20 W)
  - remote UV-VIS-IR spectroscopic imagers (30 kg/30 W)

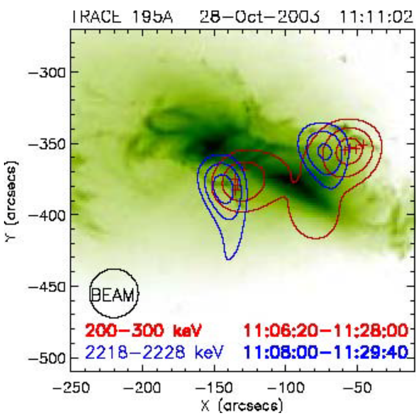
<u>Measurement Strategy:</u>

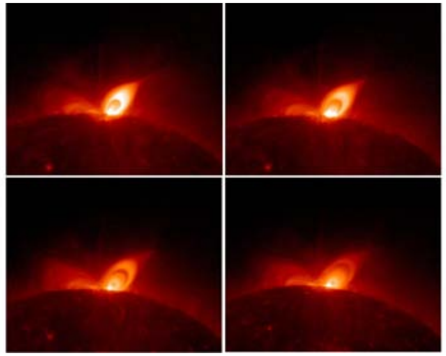
- Lunar orbit for near-lunar plasma ion, gas, mag, SEP
- Lunar limb occultation from orbit for solar corona obs.

<u>Enabling and Enhancing Technology Development:</u>

- High resolution plasma and neutral gas composition spectrometers integrated to energetic ion detectors for complete characterization of plasma/SEP interactions
- Compact steerable high-resolution UV-VIS-IR spectroscopic imaging system for solar F-Corona, lunar surface & atmosphere, and other geospace observations – not diffraction limited by s/c occulter !
- Lightweight solar-powered spacecraft bus system for flexible lunar orbital and solar observation operations

MAgnetic Reconnection in the Corona (MARCO)





Left: RHESSI/TRACE observations of gamma-ray line (blue) & hard X-ray continuum (red) footpoints straddling the flare loops, revealing both ion & electron acceleration related to reconnection.
Right: HINODE XRT image sequence showing evidence of magnetic reconnection.

Science Objective

- Understand the physics of the magnetic reconnection in the corona that initiates the release of energy for solar flares and coronal mass ejections (CMEs), and that leads to solar energetic particle (SEP) acceleration.

Observational Objectives

- Measure the temperature, density, and magnetic field in reconnection regions and follow their spatial/temporal evolution
- Measure the density, speed, and direction of the slow (~0.01~0.1 V_A) and fast (~V_A) plasma flows associated with reconnection
- Locate electron and ion acceleration regions
- Characterize the seed population for accelerated ions
- Determine the energy spectra and angular distributions of the accelerated electrons and ions, and their spatial/temporal evolution
- Determine the three-dimensional density structure, initiation time profile, and velocity of the shocks that accelerate SEPs
- Characterize the partition of energy amongst the various manifestations of energy release

Associated RFAs: F1, F2, H1, J2, J3

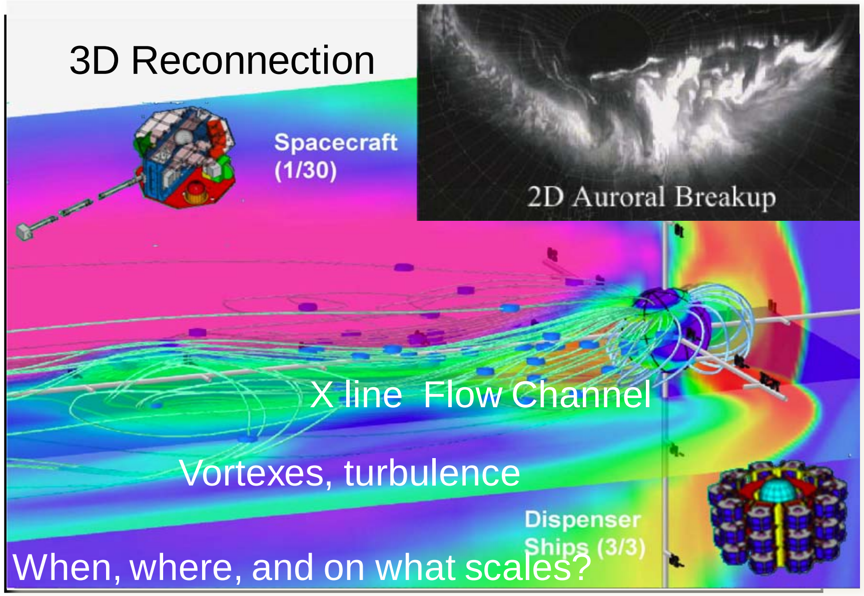
Mission Implementation

- With the next generation of instruments it will be possible to probe reconnection, transient energy release, and particle acceleration in the corona. Simultaneous comprehensive measurements by multiple space instruments are needed, in conjunction with ground-based instruments (e.g., ATST and FASR) to measure coronal magnetic fields, morphology, etc.
- MARCO combines the necessary space instrumentation on a single 3-axis stabilized spacecraft with an extendable ~20 m boom, in a low-Earth orbit.
    - Total payload resources: ~2000 kg / 1500 W / 1 TB per day
    - Operation during solar cycle 25 starting in ~2020
- Instrument Payload
- To be determined from a science & technology definition team study, with many possibilities described in other quad charts in this Roadmap
  (e.g., RAMM, FOXSI, GRIPS, GRAPE, FACTS, UVSC, COMPASS).

Key Measurements & Candidate Instruments

- Coronal magnetic fields
    - ATST (Advanced Technology Solar Telescope),
    - FASR (Frequency Agile Solar Radio observatory)
    - EUV vector magnetograph
- Plasma density, temperature , and flows
    - Soft X-ray imaging spectrometer
    - EUV/UV imaging spectrograph
    - UV spectrometer/coronagraph
    - White-light imaging coronagraph
- Suprathermal seed particles
    - UV spectrometer/coronagraph
    - Focusing optics hard X-ray spectroscopic imager
- Energetic electrons and ions
    - Focusing optics hard X-ray spectroscopic imager
    - Gamma-ray imaging spectro-polarimeter
    - Neutron spectrometer

Magnetospheric Constellation Mission



Science Objectives

- Determine how the magnetosphere stores, processes, and releases energy from the solar wind interaction:
- How does the magnetotail behave?
- How are particles injected to form the radiation belts?
- How does the magnetopause respond to the solar wind?

Mission Description

- Constellation of 30-36 ST-5 class s/c
- 15° inclination, nested orbits
- Apogees from 7-27 R_E, ΔV = 814 m/s
- Per s/c: 20 kg, 15 W, 1 kbps, 1° pointing

Measurement Strategy

- Synoptic vector measurements of magnetic field, plasma flow & energetic particles
- **Mean spacecraft separation:** 2 R_E
- **Time resolution:** 10 sec
- Mission targets are plasma sheet and low latitude magnetopause

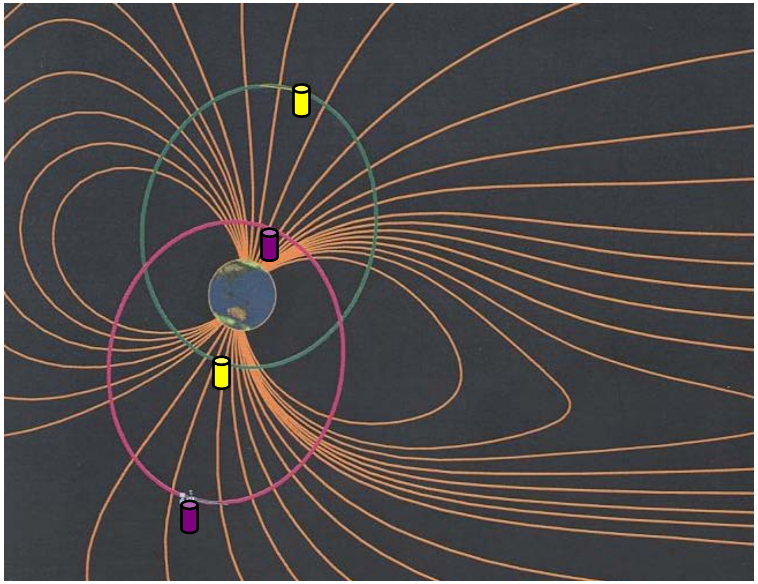
Enabling Technology Development

- None

Technology Requirements

- ST-5 design-experience base
- Fabrication, assembly and testing techniques from Iridium, GPS, other commercial, DoD constellations

Magnetospheric Sentinels



Science Objectives:

- Interhemispheric differences in acceleration/deposition
- Magnetospheric modes (SMC vs. load/unload)
- In situ Poynting flux measurements vs. auroral energy
- X ray imaging of dispersionless injections/Proton aurora
- (Monitoring/context – not science, but important)

Associated RFAs:

F3, H2, H3

Mission Implementation Description:

- **Number of spacecraft:** Ideally, 4; 2 in each orbit
- **Location:** Molniya orbits (+ & – 63°); 6, 8 or 12 hr period
- **Attitude control:** in practice, either spinner or 3-axis stabilized; ideally, stabilized
- **Number & Type of instrument(s):** tri-spectral FUV imager + telescope for hi-res; possible proton &/or X-ray imagers (Sentinel A & B) + in-situ particle and fields
- **Payload resources required:** 80 kg/60 W/200 kbps

Measurement Strategy:

- Continuous observations of global-scale auroral emission in both hemispheres

Enabling and Enhancing Technology Development:

- Space Qualification of high resolution (1024 X 1024) electron amplifying CCD detectors
- Implementation of controlled lossy compression for science missions

Maneuverable Near-Space Platform

Science Objectives:

- High res. solar imaging: photosphere, chromosphere, corona (incl. streamers, solar wind, CMEs); auroral imaging; limb sounding, absolute TSI…
- High res. spectral, spatial, temporal, Earth imaging, pollution (NO_2, SO_2, O_3), ocean color, hurricane tracking, wind speed.
- Large aperture astrophysics optical/IR telescope/interferometer

Associated RFAs:

- TBD

Mission Implementation Description:

- One spacecraft (Airship)
- Location: Near space (> 18 km altitude)
- 3-axis stabilized craft with engines, with LMATC disturbance-free payload (DFP)
- Mulitiple instrument capacity (1-10)
- In-situ & remote sensing, facing out or down
- Payload resources: TBD

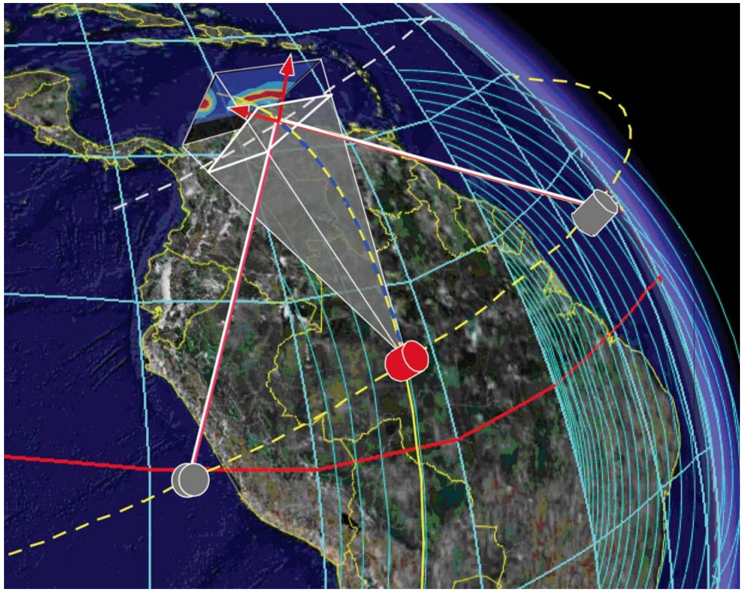
Measurement Strategy:

- Large-aperture, long-duration, stable-pointing, near-space platform

Enabling and Enhancing Technology Development:

- Long duration (months), high altitude Airship [under design by DoD]
- Image stabilization (DFP; TRL 6)
- Test platform for new technologies
- Calibration underflight

Neutral Ion Coupling Explorer (NICE)



Science Objectives:

- Understand coupling between planetary ionospheres and their upper atmospheres mediated by strong ion-neutral coupling [Science Plan, 2006]

1. How do the large scale atmospheric dynamics control the Earth's ionosphere.
2. What causes the day to day variability in the Earth's ionosphere.
3. What causes the ionospheric plasma enhancement during storms.

Associated RFAs:

F3, F4, H2, J4

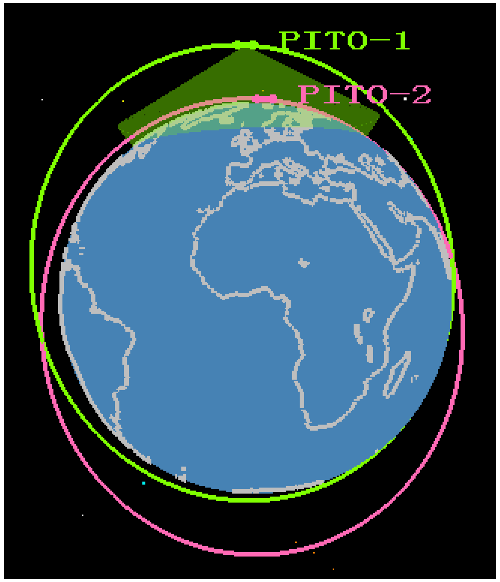
Mission Implementation Description:

- **Number of spacecraft:** 1
- **Location:** circular orbit alt.= 550 km, incl.=24°
- **Attitude control:** Nadir pointed 3-axis stabilized
- **Instruments:** (1) Fabry-Perot (remote), (2) FUV imager (remote), (3) EUV profiler (remote), (4) Ion Velocity Meter (in situ/remote), all TRL = > 6.
- **Payload resources required (mass/pwr/tlm):** 72.4kg/59.4W/30.6 kb/s (S band) Measurement Strategy: Low inclination orbit remote instruments look at northward limb, FUV/EUV characterizes thermosphere/ionosphere. Wind vector profiles are measured on same limb. Equipotential field lines allow interpretation of in situ ion drift as E field in same limb region. Obtains composition (neutral and ion), neutral winds and temperatures.

Enabling and Enhancing Technology Development:

- All required technologies are currently available to perform the NICE baseline mission, however technology development will increase the value of the retrieved data.
- Development of observation-specific on- board data compression schemes.
- Development of inversion and tomographic algorithms for 3-D interpretation.
- Higher dynamic range (speed) photon counting FUV detectors would simplify calibrations and thus improve data quality.

Paired Ionosphere-Thermosphere Orbiters (PITO)



Science Objectives:

- Combine in situ data, imaging and profiling to unravel the complex interplay between process on different scales and in different regions and assess how the I-T system responds to magnetospheric and neutral forcing, including
- The causes of ionospheric density irregularities < 1000 km
- Composition changes in the aurora
- High-latitude electrodynamical control of the global circulation of the atmosphere
- Connections between equatorial depletions and atmospheric disturbances

Associated RFAs:

F2, F3, H2, H3,J1,J4

Mission Implementation Description:

- **Number of spacecraft:** 2
- **Location:** LEO (200 x 2000 km)
- **Attitude control:** 3-axis stabilized
- **Number of instruments packages:** 4
- **Payload resources required:** 400 kg

Measurement Strategy:

- Paired satellites for simultaneous observation of large and small scale ionosphere-thermosphere phenomena in two regions of the atmosphere and the coupling between them

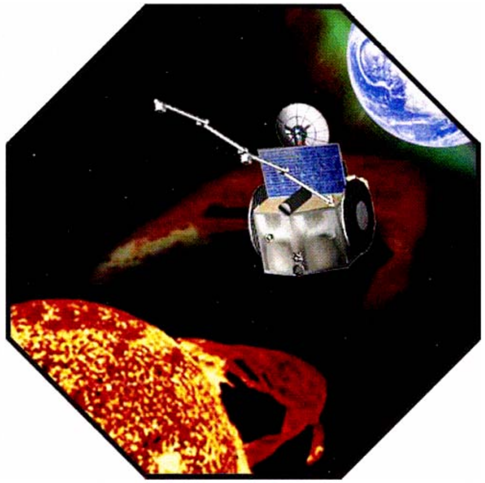
Enabling and Enhancing Technology Development:

- None

Enhancing technology:

- Spaceborne lidar would enhance the mission

PERSEUS Mission
"Investigating heliospheric dynamics from L1"



PERSEUS

Science Objectives:

- Explore changes in heliospheric material and flow impacting Earth and planets, outward to the heliospheric outer boundary
- Understand the relationship between CMEs and CIRs
- Investigate transient phenomena effects on Earth and planetary bodies
- Understand plasma transport and solar wind physics
- Measure the societal impacts of solar events

Associated Research Focus Areas:

- Understand the structure and dynamics of the Sun and solar wind
- Determine heliosphere evolution and its interaction with the galaxy
- Understand the response of planet magnetospheres and atmospheres
- Discover how heliospheric magnetic fields evolve
- Understand coupling across multiple scale lengths
- Develop prediction of solar activity and solar disturbance evolution
- Specify and enable prediction of changes to the Earth's environment

Mission Implementation Description:

- **Number of spacecraft:** One, Pegasus launched
- **Location:** L1
- **Attitude control:** 3-axis stabilized, sun pointing
- **Number of instruments:** 4
- **Type of instruments:** 2 remote sensors (All-Sky Imager, Coronagraph), 2 in situ monitors (Plasma Monitor, Magnetometer) (TRL 6-9)
- **Payload resources required:** mass = 17.5 kg, pwr = 24 W, tlm = 10^4 k bits s^{-1} to USN

Measurement Strategy:

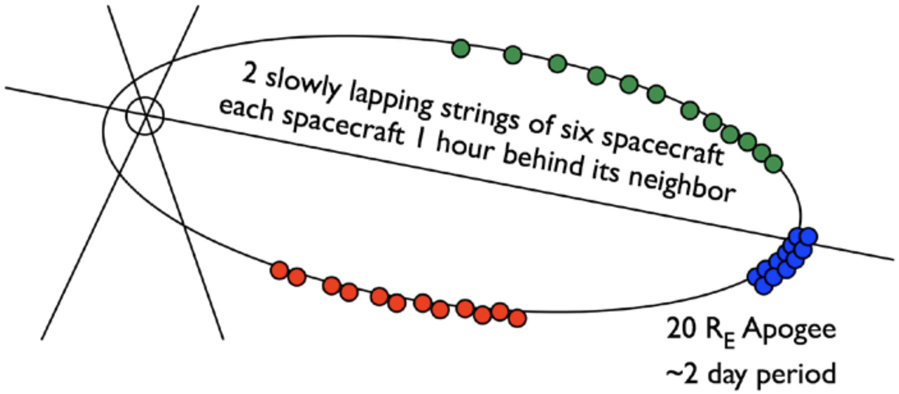
- All-the-sky all-the-time remote-sensing imagery from L_1 from 2.5 solar radii to ~180º anti-solar
- L1 ground truth and in-situ monitor forecast capability

Enabling and Enhancing Technology Development:

- Light-weight 3-axis stabilized s/c bus technology enables a Pegasus launch to L1 for long-duration heliospheric science exploration
- Light-weight hemispheric imager concept givess "all sky, all time" coverage; excludes solar background illumination.
- SMEI and NASA STEREO Heliospheric Imager remote sensors prove and enable concept
- 3D MHD heliospheric models provide 3D interpretation
- 3D reconstructions of the heliosphere at high resolution on super-computers allows modeling in near real time
- Further ground truth verification provided by in situ and remote-sensing measurements from multiple missions

The Profile Mission

- Profile achieves multiple science objectives by using different formations throughout the mission.
- “lapping” string-of-pearls formation (two identical strings of six spacecraft each per mothership) allows evolution of Profile over time (e.g. red, blue, and green formations below will naturally result from orbital dynamics)



Science Objectives:

- Understanding of the effects of disturbances from the Sun, the dynamics of substorms from the tail, and the nature of boundary layer motions on the flanks
- How do these disturbances propagate? What roles are played by large-scale, medium-scale, and small-scale structures?
- What is the global structure (convection, magnetic field, plasma density and temperature) of the plasma sheet and how does it change during substorms?

Associated RFAs:

F1, F2, H2, J1, J4

Mission Implementation Description:

- 12 daughter spacecraft per mothership (for 24 spacecraft, use two motherships with opposing apogees)
- 7000 km x 20-25 Re, 10-15 degrees inclination
- Spin stabilized, no propulsion
- Vector magnetometer, 3-D plasma analyzer (<30 keV)
- in situ measurements using high-TRL instruments
- bus+payload requires 17 kg, 30 W, 2 kbps orbit-averaged

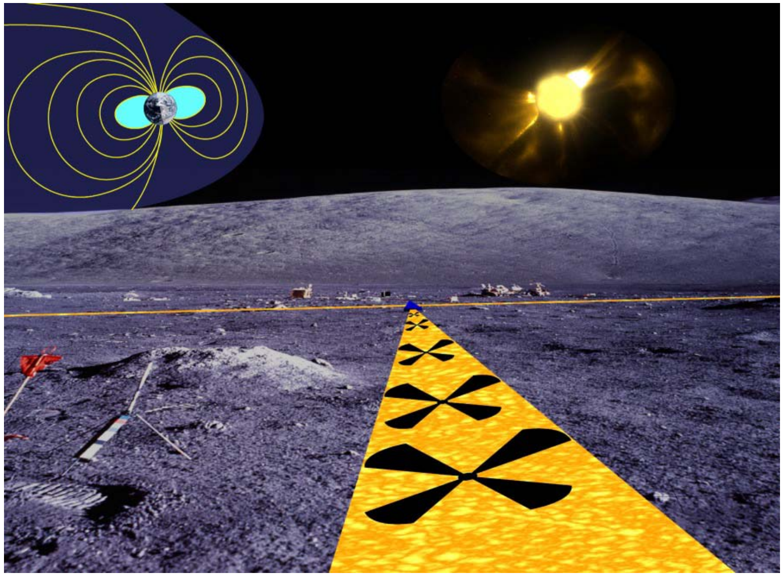
Measurement Strategy:

- Simultaneous data from all x-y cross-sections during a year as apogees precess.
- Tight “superclusters” near apogee
- Separation of spatial from temporal variations
- Repeated passes in quick succession through important regions
- Simple identical instruments provide the most science return per dollar

Enabling and Enhancing Technology Development:

- Mass-production of 12 (or 24) identical daughter spacecraft, based on ST-5 bus
- Centrifugal slingshot deployment system that can accommodate 12 daughter spacecraft per mothership
- Similar miniaturization as required for MAGCON
- For extended Profile mission (beyond 2 years), up to 6 hour eclipses could be mitigated by improved battery technology – not needed for prime 2 year mission
- Another possibility would be the use of non-volatile memory and no batteries, letting the spacecraft go to sleep during eclipse periods

Radio Observatory for Lunar Sortie Science (ROLSS)



Science Objectives:

- Understand particle acceleration in the outer solar corona by imaging solar radio bursts in that region of space (for the first time)
- Determine shock acceleration geometry in outer corona
- Determine acceleration source(s) and location(s) for complex solar radio bursts
- Understand fine structure in solar radio bursts and its relation to magnetic field and solar wind structures

Associated RFAs:

F1, F2, H1

Mission Implementation Description:

- Radio interferometric array deployed on lunar surface
- 3 arms ~1.5m wide x 500 m long of thin polyimide film with dipole antennas and leads deposited on film
- ~16 antennas per arm connected to central hub
- Hub has radio receivers, solid state memory, solar arrays, phased array downlink, thermal control, etc.
- Deployed with astronaut support (lunar sortie); rover attachment permits unrolling of film on surface
- Latitude w/i 30 deg of lunar equator = coronal viewing
- Estimated resources: 300 kg, 130 W (day), 70 Mbps

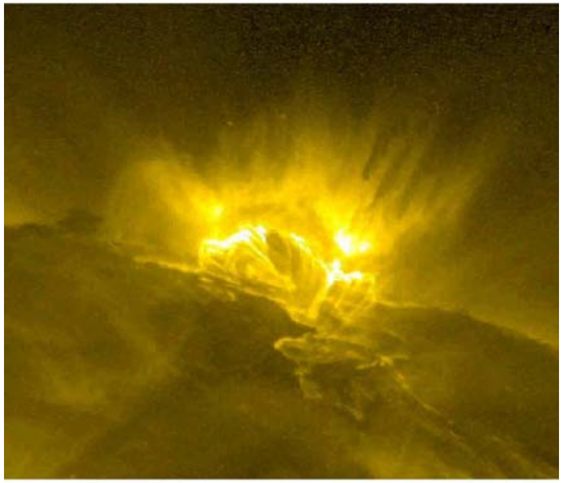
Measurement Strategy:

- aperture synthesis imaging

Enabling & Enhancing Technology Development:

- Enhance and validate polyimide film/antenna system design and TRL
- Develop complete ultra low temperature/ultra low power suite of electronics
- Develop ultra low temperature/ultra low power solid state recorder
- Apply state of art battery technology to reduce mass and to improve battery survival temperature range
- Confirm rover characteristics for deployment

Reconnection and Microscale Mission



TRACE 195A post flare loops and current sheet. Notice the dark voids threading the FeXXIV emission that reveals the current sheet. Higher resolution is required to image the substructure in reconnecting plasma.

RAM Fundamental Question:

What are the underlying physical processes by which high energy particles and radiation are created throughout the plasma universe?

Science Objectives:

•What micro-scale instabilities lead to global effects?

•Where are the regions of particle acceleration?

•What are the mechanisms that lead to reconnection?

•Where are the reconnection regions and what is their topology?

Associated RFAs:

F1, F2, H1

Why is RAM important?

•RAM will locate and measure the high energy radiation and particles at their source in the Sun's outer atmosphere.

When will RAM be ready?

•RAM is ready for a Science Definition Team.

Mission Implementation Description:

- One Geostationary 3-axis stabilized spacecraft
- Payload:1600kg/1200W/1.3TB/day (30% reserves included)
- Coronal Imaging Spectroscopy Instrumentation:
- High resolution EUV/UV spectrograph (0.25"/pixel)
- X-ray imaging Spectroscopy (2" imaging, 2eV resolution from 0.2 to 10keV, photon counting)
- Hard X-ray Imaging Spectroscopy (~15"/pixel, 5-80keV)
- Multi wavelength high resolution EUV/UV imagers (0.1"/pixel)

- **Measurement Strategy:**
- Observe the site of particle acceleration.
- Quantify the inflows and outflows associated with reconnection.
- Plasma properties from 1-50MK with high spatial & temporal resolution.
- Detect the sub-structures responsible for energy conversion.

Enabling and Enhancing Technology Development:

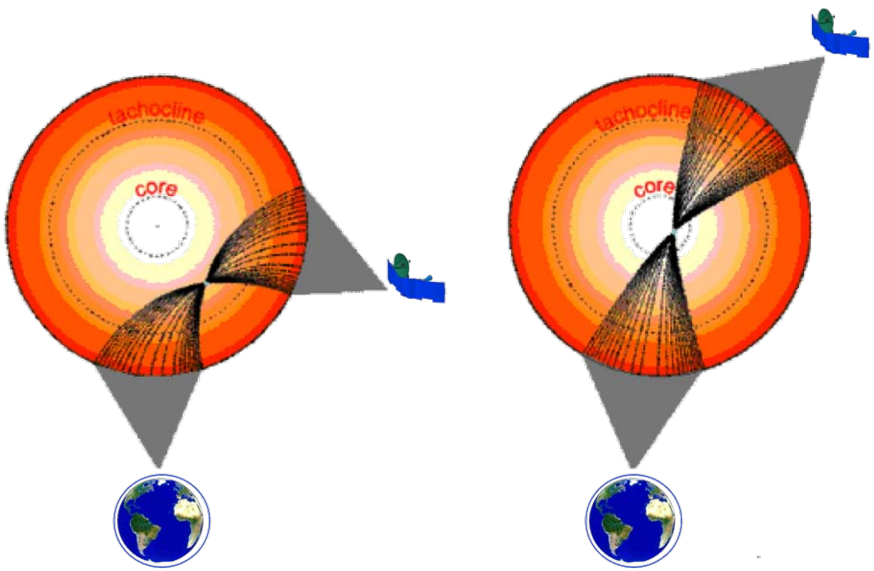
Enabling Technologies (current TRL estimate):

- Large format, high count rate X-ray calorimeter TRL 4-5: Based on Astro-E II and IXO development efforts.

Technologies at TRL ≥ 6

- Hard X-ray focusing optics TRL 6: based on HERO, HEFT
- Extendable Optical Bench TRL 7: RAM can re-use e.g. the NewSTAR deployable mast.
- Image stabilization techniques TRL 6: RAM extends techniques from TRACE and SOHO/MDI and SDO/AIA missions.
- Multilayers for the high resolution imager optics TRL 9: uses same as TRACE and SDO/AIA heritage.

Solar Activity Farside Investigation (SAFARI)



Science Objectives:

Safari will quantify:

- Where in the sun solar variability originates
- How magnetic fields emerge and evolve on the solar surface
- How solar magnetic fields map into the global heliospheric structure

- These objectives will be achieved by using time-distance and other helioseismology techniques to probe the deep solar interior and by measuring magnetic fields over a wide range of solar longitudes.

Associated RFAs:

F4, H1, J2

Measurement Strategy:

Safari will acquire simultaneous measurements of photospheric velocity and magnetic fields from two separate and varying solar longitudes (one near-Earth) to probe the deep interior of the sun and track the evolution of magnetic activity

Mission Implementation Description:

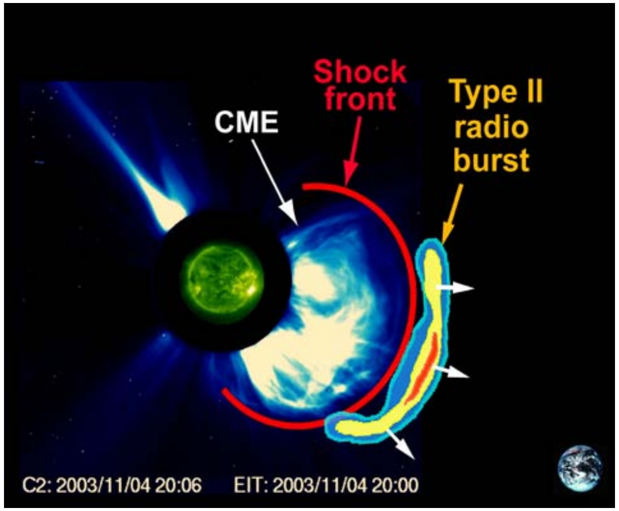
- Single spacecraft launched by Taurus class L/V
- Operational orbit: Earth-leading, 2 yr duration
- Spacecraft pointing: +/- 0.5° control, knowledge +/- 0.1°
- Weekly data volume: ≈30 Gbit
- Compact Doppler-magnetograph
- Instrument pointing: +/- 0.5 arc-s (w/ fast steering mirror)
- 8 kg, 15 W, Average data acquisition Rate ~42 kbps
- up to 5” spatial resolution
- Velocity sensitivity < 10 m/s/pixel
- Longitudinal magnetic field sensitivity ~3G

Technology Development:

- Compact Doppler magnetograph
  - magneto-optical filter TRL 4

Solar Imaging Radio Array (SIRA)

SIRA will image radio emission from CME-driven shocks and flare electron beams propagating into the inner heliosphere at frequencies inaccessible to ground based radio telescopes.



Science Objectives:

- Enhance understanding of interplanetary propagation and evolution of coronal mass ejections (CMEs) using radio images of CME-driven shocks, plasmoids, and electron beams
- Enhance understanding of particle acceleration & transport using images of radio bursts produced by electrons
- Use radio imaging near Sun to predict hazardous space weather
- Obtain and analyze the first full-sky maps from 0.1 to 15 MHz

Associated RFAs:

F1, F2, H1

Mission Implementation Description:

- Microsat constellation of 12-16 identical s/c
- Microsat: 30 kg (wet), 90 W, use of ST-5 bus
- Payload: 10 kg/sat, 10 W/sat
- Carrier/mother: buffers/xmits (Ka-band) d/l
- ΔV: 100 m/s (carrier), ~7 m/s (microsat)
- Ellipsoid constellation, 1 km diameter at L_1
- 2 high-heritage antennas & receivers per s/c
- Image synthesis done on the ground at SIRA Science Centers

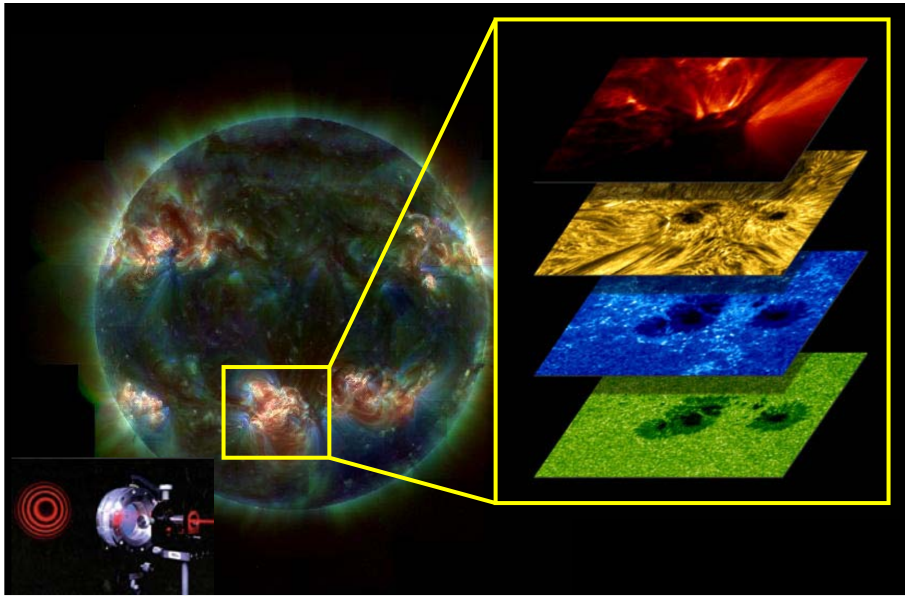
Measurement Strategy:

- Imaging at ~12 frequencies corresponding to ~2 R_{SUN} – 1 AU
- 2-bit Nyquist sampling at each frequency
- ~2.4 GB science data per day per microsat
- “Snapshot” processing on ground for space weather prediction

Enabling and Enhancing Technology Development:

- Low cost intersatellite ranging with 3 m accuracy to ranges of 50 km is simple to build, but has not been tested in flight
- SIRA and other Ka-band users need more ground station capacity

Solar MAgnetized Regions Tomograph (SMART)



Science Objectives:

- Reveal how magnetic fields extend into the solar corona, where measurements do not exist.
- Understand when, why, and how is magnetic energy released in solar flares
- Determine what heats the solar corona

Associated Heliophysics RFAs:

F1, H1, J1, J2

Mission Implementation Description:

- One spacecraft at polar, Sun-synchronous (600 km) orbit, with solar-pointed attitude control
- One remote sensing vector magnetograph (TRL 5)
- Relatively light-weight (600 kg), low-power (600W), with a telemetry of approx. 4 Mbps

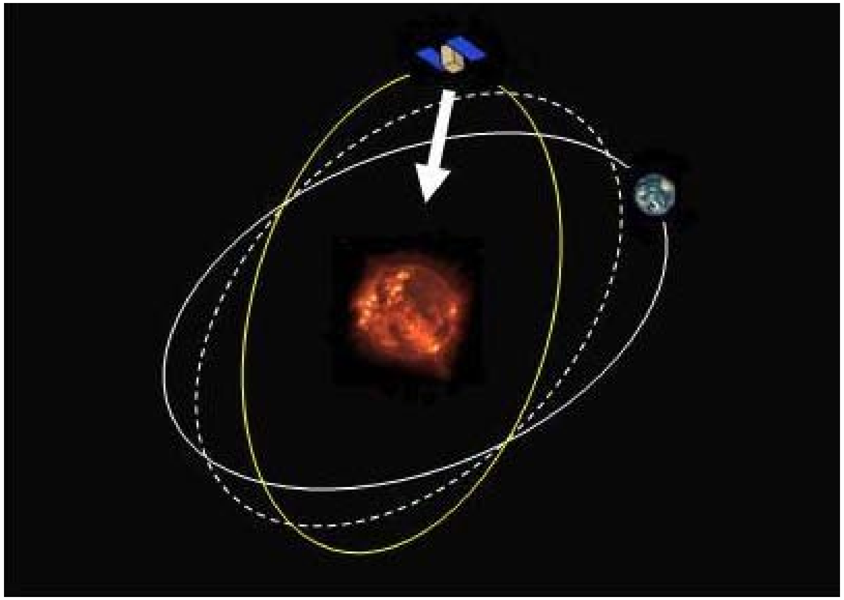
Measurement Strategy:

- Provide the first-ever three-dimensional tomographic magnetic field measurements of solar active regions and the quiet Sun in sufficiently high quality to yield an unprecedented science return

Enabling and Enhancing Technology Development:

- Lithium-niobate, solid, Fabry-Perot etalon filter
- A 50-cm aperture solar optical telescope
- Vector magnetograph able to switch to a number of magnetically sensitive spectral lines formed at different heights in the solar atmosphere
- Small integration time, (a few minutes) to enable nearly simultaneous coverage of the various layers
- High cadence, to enable detailed evolution coverage
- Previous experience / heritage exists through the balloon-borne Flare Genesis Experiment

JAXA SOLAR-C Plan-A



Science Objectives:

- Understand the internal structure of the Sun and the solar dynamo mechanism
- Understand the mechanism for high-speed solar wind
- Understand the variability of environments (space weather) in inner heliosphere with distance from the plane of the ecliptic

Associated RFAs:

F1, F2, F4, H1, H3, H4, J1, J2, J3, J4

Mission Description:

- A three-axis stabilized spacecraft in a high-inclination orbit by assists of JAXA ion engines and earth flyby
- Maintains 1AU distance
- Photospheric magnetic and Doppler velocity field observation with transition-region & coronal imaging and spectroscopic observations

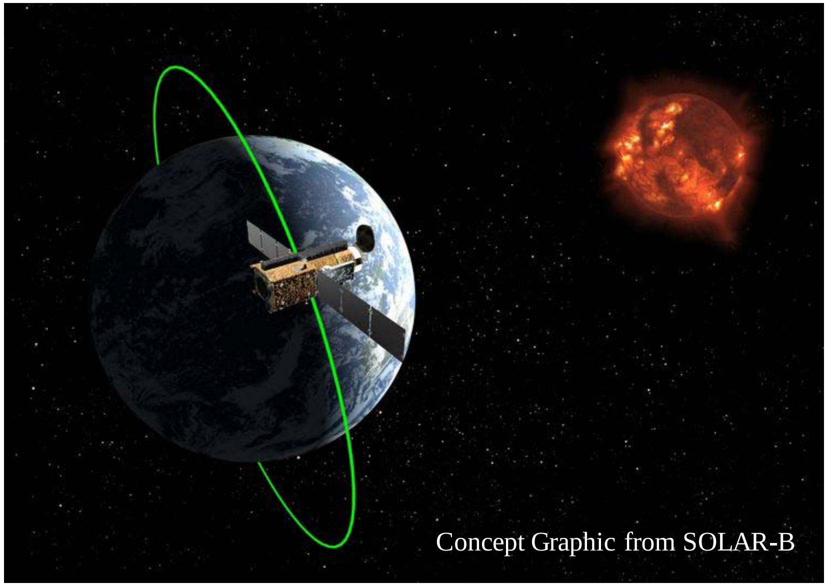
Measurement Strategy:

- Helioseismology from high-inclination orbit in coordination with an observatory near and/or on the Earth
- Direct access to polar regions as a source of high-speed solar wind and as critical area for solar dynamo
- Auxiliary in-situ measurements of inner heliosphere at ~1AU with various orbit inclinations

Enabling and Enhancing Technology Development:

- High-thrust and long-life ion engines
- High-level power system for ion engines
- High-data rate interplanetary telemetry

JAXA SOLAR-C Plan-B


Concept Graphic from SOLAR-B

Science Objectives:

- Understand the solar chromospheric and coronal heating mechanisms by enhanced spectroscopic diagnostic capability
- Understand the plasma dynamics throughout the outer solar atmosphere by high-throughput instruments
- Understand the acceleration mechanism for fast and slow solar winds

Associated RFAs:

F1, F2, F4, H1, H3, H4, J1, J2, J3, J4

Mission Description:

- A three-axis stabilized spacecraft in a sun-synchronous polar orbit or geosynchronous orbit or equivalent
- High-throughput visible and UV imaging and spectroscopy, a coronal imaging, and EUV imaging spectroscopy

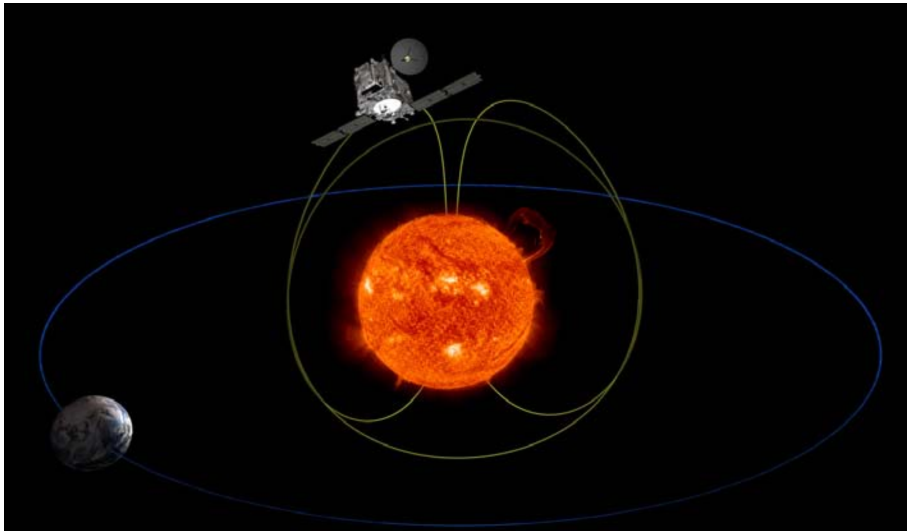
Measurement Strategy:

- Emphasis on high-spatial and high-time resolution spectroscopy for investigating dynamic chromosphere and transition region with observations of photosphere and corona
- Higher spatial resolution in transition region and coronal observations than that for Hinode

Enabling and Enhancing Technology Development:

- Stringent contamination control for UV and EUV instruments
- Image stabilization technique for all instruments
- High-data rate telemetry (10-100 times higher than that used in Hinode)

Solar Polar Imager (aka POLARIS)



SPI's 4 month solar polar orbit viewed in Earth-fixed frame

Science Objectives:

- Dynamo: Helioseismology & magnetic fields of polar regions
- Polar view of corona,CMEs, solar irradiance for structure,evolution and space weather prediction
- Link high latitude solar wind & energetic particles to coronal sources

Associated RFAs:

F2, F4, H1, J2, J3

Mission Implementation Description:

- SC in highly inclined (~75°) 3:1 Earth-resonant heliocentric 0.48 AU orbit
- Low-thrust trajectory with solar sail delivery (electric propulsion is another option)
- 5 remote sensing, 3 in-situ instruments, 3-axis stabilized s/c 43 kg, 52 W, Avg. Acquisition Rate ~100 kbps

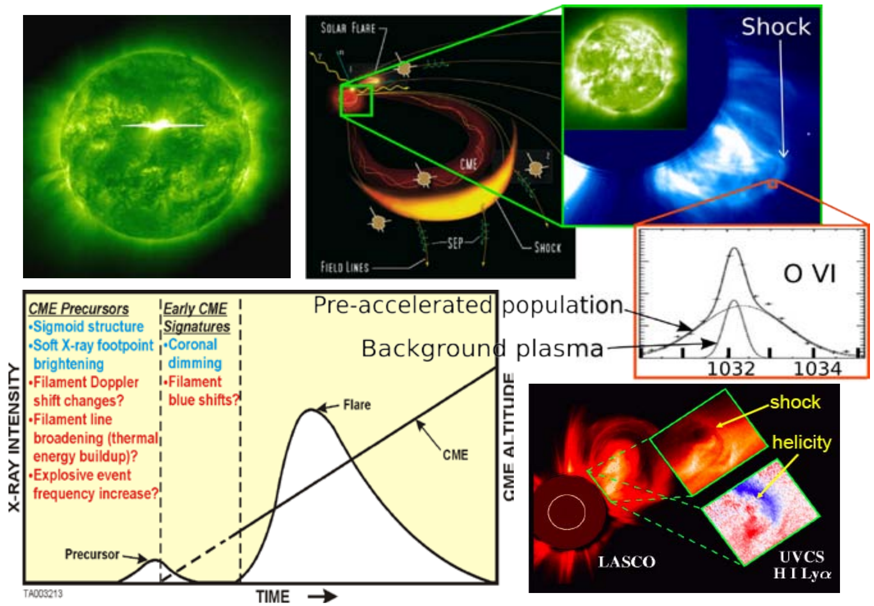
Measurement Strategy:

- Surface & interior flows for helioseismology
- Polar magnetic fields and flux transport
- Polar coronal imaging in white light and EUV
- UV Spectrometer for outflow velocities
- In situ magnetic fields, solar wind and energetic particles
- Total solar irradiance variability

Enabling Technology Development:

- Solar sail (current launch vehicles)
- Constellation may enable SEP implementation

Space Weather Imaging Sentinel (SWIS)



Science Objectives:

- Determine the most relevant observational signatures of flare, CME, and Solar Particle Event (SPE) eruption
- Identify precursor signatures which can be used to forecast flare, CME, and SPE eruption
- Identify what is needed to improve our ability to nowcast and forecast space weather & SPEs
- Identify the physical mechanisms of mass flow and energy release in the solar atmosphere
- Determine the interaction and connectivity of structures throughout the solar atmosphere

Associated RFAs:

F1, F2, J2

Mission Description:

- 1 spacecraft, 5 Hi-TRL instruments
- L1 or Geo or 98°, 600 km sun-synch orbit
- continuous solar viewing
- 3-axis stabilized, 30 arc-sec pointing capability
- Payload: 40 kg, 53 W, 2.2 Mbps

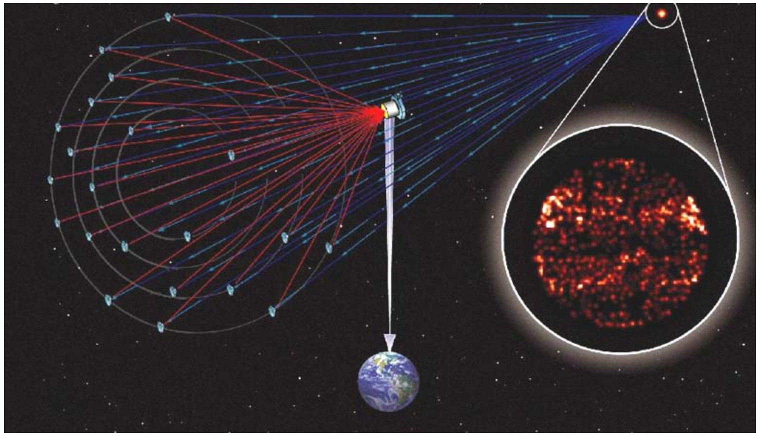
Measurement Strategy:

- UV/EUV Imaging Spectrograph for flow velocities & energy buildup & release signatures, both on the disk and off-limb (out to 3 Rs)
- Filter Magnetograph for surface magnetic field measurements
- Chromospheric/Coronal EUV Imagers for morphology and dynamics
- Energetic Particles (SEP) measurements for event characterization
- Coronagraph for detection & characterization of Halo CMEs

Enabling and Enhancing Technology Development:

- High cadence imaging spectrograph development
- Low mass/power instrumentation
- Advanced communication/DSN for future deployment to Sentinel or remote locations

Stellar Imager (SI)



SI is a UV/optical deep-space telescope to image stars like the Sun with 0.1 milli-arcsec resolution, to help understand the solar dynamo, the internal structure and dynamics of magnetically active stars, how magnetic activity drives space weather on time scales of years to billions of years, and how that affects planetary climates and habitability.

Science Objectives:

Develop and test a predictive dynamo model for the Sun by:

- Observing the patterns in surface magnetic activity for a large sample of Sun-like stars (with ~1000 res. elements on surfaces of nearby stars)
- Imaging the structure and differential rotation of stellar interiors via asteroseismology with over 30 resolution elements on stellar disks
- Carrying out a population study of Sun-like stars to determine the dependence of dynamo action on mass, internal structure, flow patterns, and time. This will enable testing of dynamo models over a few years of observations of many stars, instead of over many decades using only the Sun.

Associated Research Focus Areas:

F4, H1, H4, J2

Mission Implementation:

- Interferometer with 9 to 31 formation-flying spacecraft. The number of mirror elements determines the time needed to complete an image, and thus the number of possible targets
- **Location:** Sun-Earth L2
- **Attitude control:** 3-axis stabilized
- **Type of instrument(s):** remote sensing imagers
- **Payload resources:** up to 5000kg/3000W/1-5Mbps

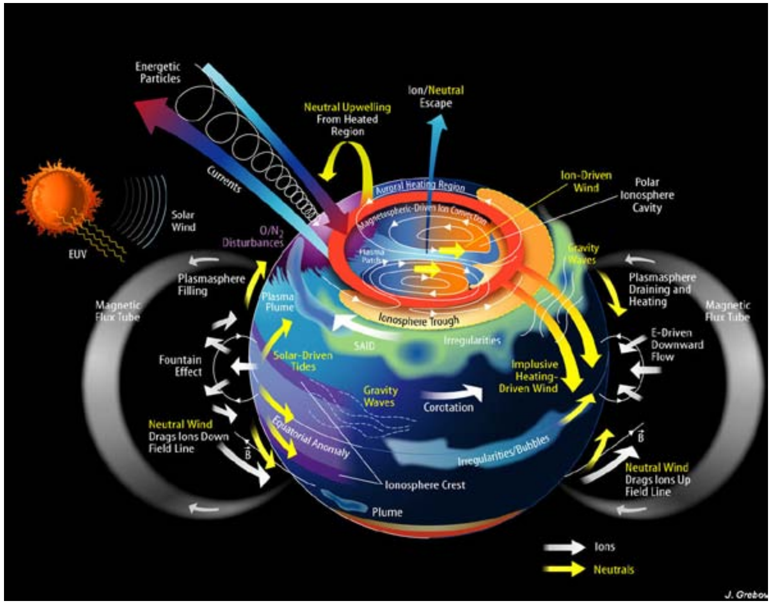
Measurement Strategy:

- UV/optical interferometric spectral imaging
- angular resolution of images better than 0.1 milli-arcsec
- spectral resolution R=100 requirement, R=20000 goal
- measure internal structure & rotation of select stars with <50,000 km resolution in & below convective zones

Enabling and Enhancing Technology Development:

- Precision formation flying with low-mass, efficient propulsion
- Optics control and beam combining with ~5nm precision
- Integration and test of many-element, long baseline distributed aperture system
- Mass-production of lightweight, UV-quality mirrors

Storm-Time Observations by Remote and In Situ Measurements (STORM)



Science Objectives:

- ***Science/Exploration:*** How does the upper atmosphere respond to forcing from above and below? What are the important drivers? What physics is missing in the ITM models that prevents us from having a real understanding or a predictive capability?
- ***Programmatic:*** This mission addresses key LWS objectives of understanding storm-time response for DoD and DoC customers and addresses some of the key STP science issues as well.

Associated RFAs:

F2, F3, F4, H1, H2, H3, H4, J4

Mission Implementation Description:

- 3 FUV sensors at GEO, 2 small satellites in LEO, 4 microsats in LEO, 4 microsats in eccentric orbits for in situ density and drag measurements, hypersonic vehicle (optional) for focused investigations.
- All satellites are 3-axis controlled but have different purposes and requirements
- FUV imagers at geo, ion density and drift measurements (in situ) from LEO, density and energetics observations from fixed LST and variable LST orbits. All have high TRL.

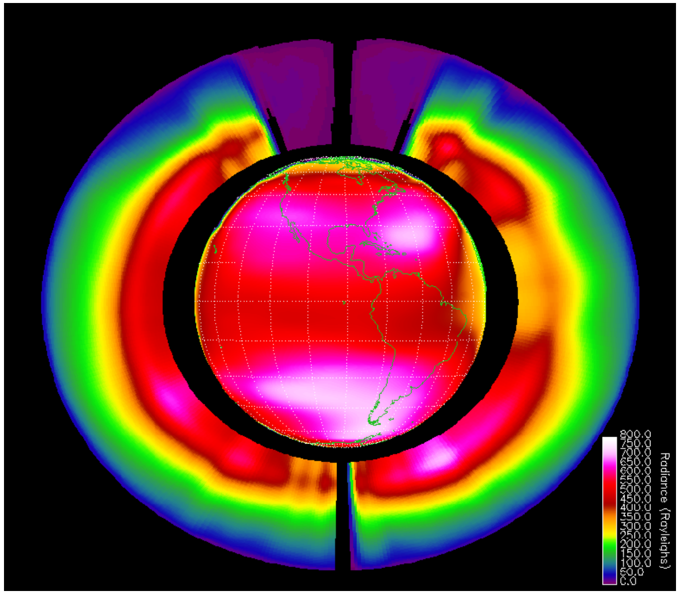
Measurement Strategy:

- Don't try to do everything from one platform – use the right tool for the job!

Enabling and Enhancing Technology Development:

- Micro satellites with 3 axis stabilization
- Miniature cryocoolers
- Solar blind detectors
- Hypersonic vehicles

Thermosphere Ionosphere Global and Regional Imaging in Space and Time (TIGRIST)



Science Questions:

1. What is the prompt global-scale ionospheric response to geomagnetic storms?
2. What is the extended response of the thermosphere and the global scale ionosphere to geomagnetic storms?
3. How do traveling ionospheric disturbances develop and propagate?
4. What affects the day to day variability of equatorial ionosphere?
5. What are the temporal and spatial properties of high latitude I-T upflows and out flows?

Associated RFAs:

F2, F3, H1, H2, J4

Mission Implementation Description:

- **Concept:** The TIGRIST payload will be "piggybacked" on a commercial communications satellite over the western hemisphere. The launch services and spacecraft accommodations will managed through the GEO Quick Ride program and the Goddard Space Flight Center (GSFC).
- **Instruments:** (1) Steerable FUV/EUV regional scale imager (RSI) at 83.4 nm, 130.4 nm, 135.6nm, and 155.0 nm with a spatial resolution of 4 km and 1000x1000km FOV, (2) Fixed FUV full disk global scale imager (GSI) 135.6 nm and 155.0 nm with a resolution of 30 km.
- **Payload resources required (mass/pwr/tlm):** 109.6kg (30% margin)/99.8W (30% margin)/1.0 Mb/s (maximum)

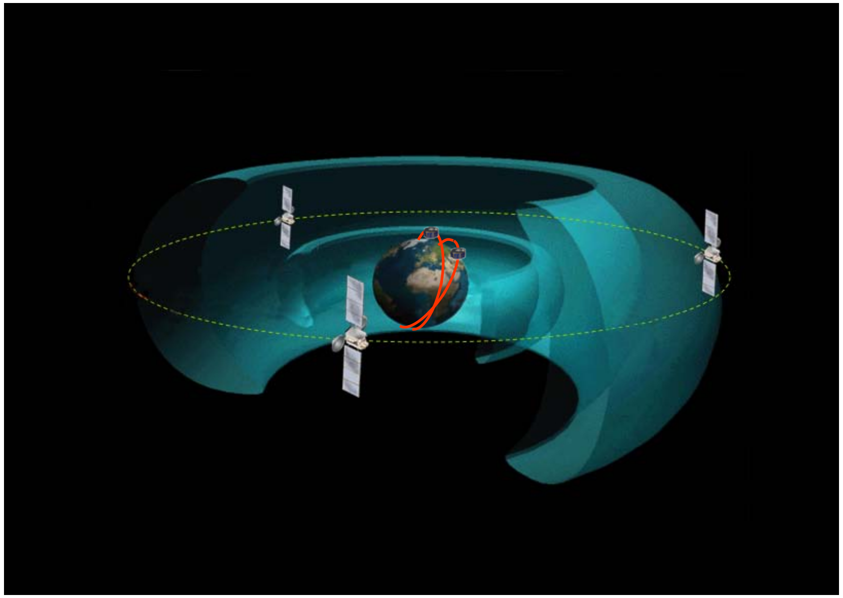
Measurement Strategy:

- GSI images N_e dayside, N_e and O/N_2 on limb dayside and high resolution regional N_e on nightside. GSI images full disk O/N_2 on dayside and full disk N_e on nightside

Enabling and Enhancing Technology Development:

- All required technologies are currently available to perform the TIGRIST baseline mission, however technology development will increase the value of the retrieved data.
- Development 83.4 nm filter coatings to enhance rejection of undesirable spectral lines

Thermosphere Ionosphere Storm Observatory (TISO)



Science Objectives:

- Determine how the thermosphere-ionosphere responds to forcing from above and from below
- Understand how geomagnetic storms alter the structure of the thermosphere and ionosphere
- Understand the global response of the thermosphere-ionosphere to solar extreme-ultraviolet variability
- Determine the global tidal structure and response to atmospheric waves

Associated RFAs:

F3, H2, J4

Mission Implementation Description:

- Number of spacecraft: 3 GEO + 1 LEO
- Number of instruments: 3 GEO + 2 at LEO
- Types of instruments:
  - GEO: Remote sensing UV imager, TRL≥ 6
  - LEO: In-situ plasma/neutral parameters, TRL≥ 6
- Payload resources at GEO: 30 kg/30 W/5.0 Mbps
- Spacecraft:
  - GEO: Low-cost ride on commercial comsat
  - LEO: Pegasus-class, high-inclination

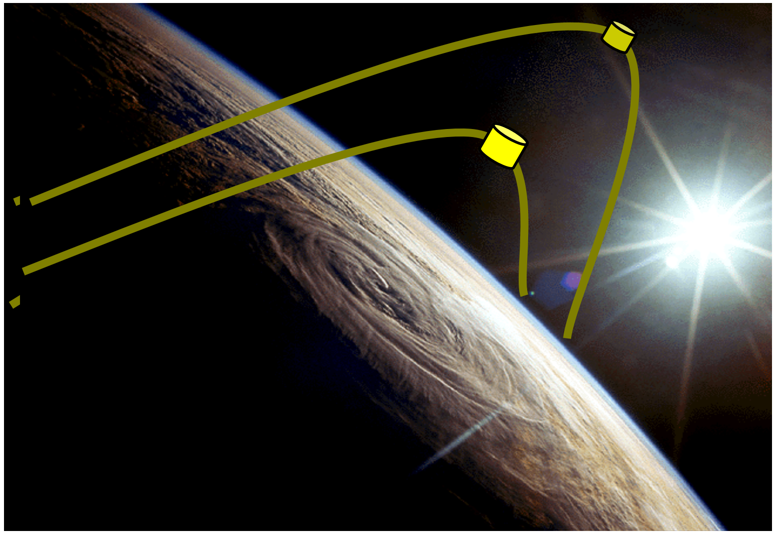
Enabling Technology Development:

- Accommodation on commercial communications satellite with real-time data capability
- Advanced development of delay-line UV detectors

Measurement Strategy:

- Simultaneous global imaging of temperature and atomic/molecular composition ratio during the day
- Comprehensive global imaging of peak electron density during night
- High-resolution measurements of low-latitude ionospheric irregularities at night
- Limb measurements of neutral composition altitude profiles and exospheric temperature
- Ability to distinguish tidal and storm effects as a function of both local time and longitude
- LEO satellite provides measurements of auroral energetics and plasma-neutral interactions

Tropical Atmosphere/Ionosphere/ Thermosphere (TRAIT) Coupler



Science Objectives:

- Determine energy deposition from the low and middle atmospheric sources, such as tropical storm systems, into the Earth's upper atmosphere and ionosphere.
- Determine the neutral and electro-dynamical coupling between the Earth's low latitude mesosphere, thermosphere, ionosphere, and inner plasmasphere.

Associated RFAs:

F2.4, F3.1, F3.4, H2.3, J4.4

Mission Implementation Description:

- **Number of spacecraft:** 2
- **Location:** LEO with low inclination (< 20°); 2 with elliptical orbits (250 x 1500 km) Apogees: 180° apart, Perigee: dipping as low as 150 km
- **Attitude control:** All spacecraft three-axis stabilized, momentum biased at 1 RPO
- **Instrumentation:** Combination of in-situ and remote sensing instrumentation suite. TRL > 8 for all instruments.
- **Payload resources:** 2 S/C, payload adapter, prop sys, and fuel: approx. 1400 kg

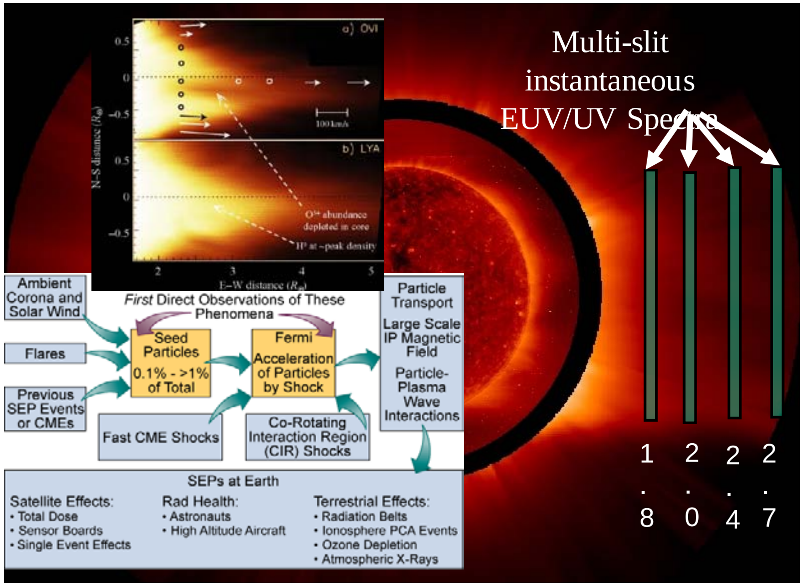
Measurement Strategy:

- The two dipping satellites provide investigations of vertical coupling through continuous coverage in each orbit. Remote sensing: gravity waves, airglow, neutral winds, plasma density. In-situ: electric fields, magnetic fields, thermal, energetic plasma, neutral density, winds, lightning

Enabling and Enhancing Technology Development:

- No "Enabling" technology required.
- New enhancing technology should reduce spacecraft cost by 10%.

UV Spectro-Coronagraphic Observations of Solar Energetic Particle Related Phenomena



Science Objectives:

- Parameterize the coronal suprathermal seed population and its role in the production of SEPs.
- Characterize the sources of SEPs and how they are accelerated to high energy.
- Provide a Space Environment predictive tool for the most geo-effective SEP events.

Associated RFAs:

F2, H1, J2

Mission Implementation Description:

- Atlas, 650 km Sun-synchronous (~98.6°) orbit
- 3-axis stabilized, Sun-pointing, Solar array powered
- EUV/UV imaging multi-slit spectro-coronagraph
- White light imaging coronagraph
- Payload mass: 250 kg, Power: 150 W, Data Rate: 10 Mbps

Technology Development:

- Mission can be accomplished with no new technology.
- Mission requires smaller pathfinder missions to identify key observables for measuring the suprathermal seed population distribution and the impact of the CME shock on the coronal material.

Measurement Strategy:

- Observe with externally occulted EUV/UV and WL coronagraphs the spatial distribution of temperature, outflow velocity (via Doppler dimming) and Line-of-sight Doppler velocity, intensity, and density of multiple ions and electrons in the corona from 1.5 to 6 Solar radii.
- Provide high resolution EUV/UV spectral line profiles of ions with various charge to mass ratios including OVI, He II, H, and other species with bright resonance scattering simultaneously at multiple heights in the corona.
- Provide spectral profiles of the non-thermal distribution of OVI, He II, and H due to suprathermal particles.